MANEJO DEL SUELO Y DESERTIFICACIÓN

Entre la ciencia y la praxis

TESIS DOCTORAL

Celia Barbero Sierra

–Octubre de 2015–

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La presente tesis ha sido realizada en el Departamento de Ecología de la Universidad Autónoma de Madrid, en colaboración con el Departamento de Geología y Geoquímica de esta misma Universidad y con el Departamento de Investigación Aplicada y Extensión Agraria del Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario (IMIDRA).

Edición y diseño: Carolina Batanero Pérez. Carolcat comunicación/ www.carolcat.com

A mi padre, Ángel Barbero Oporto

In memoriam

Agradecimientos

Por fin llegó el momento y qué difícil es no ponerse sentimental al cerrar esta andadura. Hace más de diez años, que recién acabada la licenciatura y algo desorientada, empezaba una travesía que a rachas estuvo a la deriva, pero que finalmente ha llegado a puerto. En estas idas y venidas sin duda la parte más bella son las personas que han hecho parte del camino. Pedacitos de esta tesis se deben a cada una de ellas y especialmente a:

Carmen García Fernández, por todo el apoyo y atención recibida en la primera fase de una tesis que no llegó a ser. Los recuerdos transamazónicos son un regalo que siempre me acompañará.

Manuel Ruíz Pérez, por mantener las puertas abiertas y reengancharme a esta aventura; sin ti nunca hubiera sucedido. Tu capacidad para motivar, escuchar, estimular las ganas de aprender y sobre todo tu generosidad van mucho más allá de la responsabilidad como director.

María José Marqués Pérez, fuiste la chispita necesaria para que esto arrancara de nuevo, gracias por abrirme las puertas del mundo *soil* y enseñarme que la conciliación profesional y familiar es compleja pero posible.

José Luis Cruz Maceín, por subirte a este tren en marcha cuando el destino era aún desconocido y acercarnos a los agricultores de Las Vegas.

Los agricultores y agricultoras "supervivientes", por mostrarnos un mundo nuevo a menos de 50Km de casa y porque sin vosotros la tierra moriría.

Driss, Lucas, Pedro, Amanda, David e Irene…. compis antiguos y recientes en historias de tesis.

Marta, José Manuel, Marina, Beatriz, Irene y Sara por los ratos de campo, laboratorio y gabinete compartidos.

Blanca Sastre, por la experiencia WOCAT y lo que nos queda por recorrer.

La familia ipadina, especialmente a Arantxa, Eva y Vanessa por apoyarme cuando esto sólo se veía en un horizonte lejano y enseñarme que el trabajo en buen equipo es maravilloso.

Rodrigo, Sonia, Isabel, Raúl, Mitxi, Carolina, María, Julio y el largo etcétera de amigos/as que han colaborado en las cadenas de favores para sacar esto adelante.

Sira, Álvaro, Nacho, Laura, Bea, Ferdy, Antonio y Alicia, por ser mi enlace en territorio comanche.

Los Pichones, por estar ahí desde ni sé hace cuanto y a Nuria por compartir conmigo desde el patio de la escuela… una parte de esta historia es también vuestra.

Larita, Gema, Chusa y Hugo, los ambientalitos siempre dispuestos a escuchar cómo iba el trabajo.

La familia extensa y la familia consorte, por apoyarme en este y muchos otros caminos.

Nuria, David, Iria y Martín, por estar siempre ahí, para lo bueno y lo no tan bueno, por dejarnos compartir vuestros espacios y hacer parte de los nuestros; es un gusto crecer con vosotros.

Mis chicos y mi chica en camino, por hacerme feliz. A David, por estar siempre dispuesto a editar, dar soporte técnico y logístico, cocinar, cuidar y querer y por ser un gran compañero de vida y de crianza. A Teo por demostrarme que la felicidad es un estado polifacético en el que el

agotamiento físico y la contradicción entre el corazón y la razón conviven en armonía con la alegría, la ilusión y el amor incondicional. A Lúa, por sobrellevar estoicamente la falta de descanso y seguirme el ritmo estos meses; tenemos muchas ganas de abrazarte.

Mi madre, por sacar fuerzas de la nada en el momento más complicado de su vida para que yo siguiera con la mía y por el gran equipo que hacíais cuidando, educando y queriendo.

Mi padre, por todos los recuerdos reposados que me han ayudado a madurar y perseguir este sueño hasta aquí.

Resumen

Según el Programa de Acción Nacional Contra la Desertificación (MMAMRMa, 2008), más de un tercio del territorio español es vulnerable a este proceso. No obstante, cuando se le pregunta a la ciudadanía española ¿qué es la desertificación? la respuesta es poco concreta. Hay quien lo entiende como un problema de degradación ambiental e incluso lo vincula con la evocadora imagen de las dunas en transición en parajes desérticos. Algunos grupos lo restringen a cuestiones de erosión y sequía, pero son pocos los que vinculan este fenómeno con procesos de degradación enraizados en complejas dinámicas biofísicas y humanas. Se evidencia así la brecha existente entre el conocimiento científico generado, en torno al tema, en nuestro país, uno de los más prolíficos en la materia, frente a la información y conocimiento arraigado, en el imaginario popular e institucional.

Atendiendo a la necesidad de afrontar el problema y fortalecer la concienciación y acción ciudadana acerca del mismo, en la esfera internacional la Convención Marco de Naciones Unidas de Lucha Contra la Desertificación (UNCCD, siglas en inglés), representa el principal instrumento institucional para mitigar la desertificación. La Convención establece la definición de desertificación consensuada internacionalmente y bajo su paraguas se coordinan gran parte de las iniciativas internacionales de formación, sensibilización y movilización respecto a la degradación de la tierra. Por ejemplo, en 2003, en la 58º sesión de la Asamblea General de Naciones Unidas (UNGA, siglas en inglés), se decidió que 2006 sería el Año Internacional de los Desiertos y la Desertificación. Un año más tarde, en 2007, la UNGA declaró el período 2010-2020, como la Década de los Desiertos y la Lucha Contra la Desertificación. Específicamente, la UNCCD ha establecido el período 2008-2018, como horizonte temporal, para fortalecer la implementación de la Convención a través de la Estrategia Decenal.

El presente trabajo se alinea con varios de los objetivos operacionales de la Estrategia Decenal. Principalmente con aquellos directa e indirectamente vinculados con la gestión del conocimiento relativo a la desertificación y la implementación de técnicas de manejo sostenible de la tierra; ya que la generación, conservación, gestión y transmisión de conocimiento tradicional y científico en torno a la desertificación, es una de las componentes sociales del fenómeno menos abordadas desde el ámbito científico.

La primera parte del trabajo introduce los elementos formales de la tesis, como son: el marco teórico, la definición de los objetivos y la descripción genérica de la metodología implementada. En la segunda parte se exponen los resultados compilados en ocho publicaciones científicas y la tercera parte se dedica a la síntesis de las conclusiones generales y las aportaciones específicas de la tesis.

Conceptualmente, “Manejo del suelo y desertificación: entre la ciencia y la praxis” se plantea desde un enfoque progresivo. En el capítulo cuatro, primer capítulo de resultados, se analizan los principales agentes y procesos socio-económicos involucrados en la degradación de la tierra en España, abordando la dinámica *push-pull* de transformación de suelos agrarios en suelos urbanizables.

Posteriormente, a través del análisis bibliométrico de la literatura científica internacional referente a la desertificación se abordan las aproximaciones técnicas al fenómeno. Este análisis se desarrolla en el ámbito global (capítulo cinco) y a través de dos casos específicos, como son los casos de estudio español (capítulo seis) y argentino (capítulo siete). La consideración de la literatura científica internacional publicada en España y Argentina resulta enriquecedora si se

atiende a las divergencias y concurrencias de las condiciones ecológicas, económicas y culturales de ambos países.

Los últimos capítulos de resultados retoman el entorno estatal, yendo un paso más allá en materia de gestión del conocimiento y abordando los encuentros y desencuentros entra la ciencia y la gestión del suelo en la región central de España. El capítulo ocho compara el *know-why* generado por la ciencia y el *know-how* implementado por los agricultores en la comarca agraria de Las Vegas, una zona especialmente dinámica por su localización periurbana de uno de los principales centros económicos del país (Madrid) y por estar sometida a fuertes presiones urbanísticas y socioeconómicas, que dificultan el ejercicio de la agricultura.

Por su parte, los capítulos nueve y diez se centran en el análisis de la percepción de viticultores y olivicultores de la zona centro del país, acerca del uso de técnicas de SLM como son las cubiertas vegetales, el mínimo laboreo o el laboreo siguiendo las curvas de nivel, técnicas destinadas principalmente al control de la erosión. Estos capítulos ilustran por una parte cuales son las oportunidades y limitaciones de distintos tipos de cubiertas vegetales (capítulo diez) y por otra, algunas de las causas que inciden en la receptividad o rechazo de este tipo de técnicas por parte de los usuarios (capítulo nueve).

Finalmente el capítulo 11, atendiendo al análisis de más de 60 muestras de suelo recogidas en 31 explotaciones agrarias y a la calificación que los propios usuarios hacían de ellos, compara el *know-why* científico y la calificación basada en el *know-how* tradicional. También tratan de inferirse algunas de las áreas de coincidencia y diferenciación entre ambos tipos de conocimiento y los factores que influyen en el nivel de coincidencia.

A lo largo del trabajo han surgido algunas propuestas, que pueden ser interesantes tanto desde el punto de vista de la divulgación sobre la desertificación, como para el fortalecimiento de la investigación en cuanto a las temáticas socioeconómicas involucradas o la reconsideración de las metodologías de trabajo tradicionalmente implementadas en las investigaciones relativas al suelo. Entre estas aportaciones, cabe destacar:

1.- El desarrollo del modelo teórico sobre las dinámicas *push-pull* de la desertificación en España.

Se trata de un modelo conciso, fácilmente comunicable y con el que se pueden sentir identificados múltiples actores. Por ejemplo, este modelo es muy ilustrativo para los agricultores que padecen los devenires de la PAC y el mercado agrario y que durante el boom inmobiliario han vivido de cerca la escasez de mano de obra por su fuga hacia la construcción y las oportunidades de recalificación y compra de parcelas agrarias.

2.- El análisis bibliométrico de la lectura científica ha permitido identificar dos aproximaciones claramente diferenciadas del estudio del suelo: el *soil approach* y el *land approach*.

Ambos enfoques deben integrarse equitativamente en cualquier panel asesor sobre degradación del suelo, siendo esta una conclusión a valorar por parte de la UNCCD.

La profundización en los análisis bibliométricos a través de los casos de estudio español y argentino ha evidenciado la necesidad de avanzar en el desarrollo del enfoque *land*, frente al actualmente dominante, el *soil approach*. Igualmente estos trabajos han revelado la necesidad de integrar mejor las cuestiones socioeconómicas en el estudio de la degradación del suelo, si se quiere contribuir de manera efectiva desde la ciencia, a la búsqueda de soluciones locales para frenar la desertificación.

3.- Por último, en el ámbito de la Comunidad de Madrid, se ha realizado una identificación preliminar de las coincidencias y complementariedades entre el conocimiento científico y el conocimiento agrario tradicional respecto a la caracterización físico-química del suelo y la receptividad a prácticas de manejo sostenible.

Los resultados de este ejercicio pueden ser muy útiles para reorientar los programas de capacitación coordinados desde los servicios de transferencia agraria y diseñar estrategias de sensibilización agroambiental. Esta primera aproximación, abre la puerta para la propuesta de nuevas líneas de investigación alineadas con las dificultades que los usuarios de la tierra encuentran en su día a día a la hora de equilibrar rentabilidad y sostenibilidad.

En definitiva, una las conclusiones generales de la tesis es la constatación de la necesidad urgente de fortalecer la voluntad política y la inversión económica para apoyar de manera directa y efectiva a los generadores de conocimiento formal e informal y a los gestores de la tierra, en el intercambio de experiencias y la implementación de prácticas de manejo sostenible. Desde el ámbito institucional también debe apoyarse la sensibilización y concienciación ciudadana sobre las causas antrópicas de la desertificación. Igualmente deben fomentarse medidas de mitigación concretas que atajen entre otras cosas, los principales detonantes de las dinámicas *push-pull* de conversión de tierras agrícolas. Estas y otras aportaciones de la tesis se discuten en el capítulo de conclusiones.

Abstract

The Spanish National Action Plan to Combat Desertification (MMAMRMa, 2008), points out that more than one third of the Spanish territory is vulnerable to this process. Nevertheless, when Spanish citizenship is asked about what desertification is, the answer it is not definite. For some people it is a problem of environmental degradation and they even link it with the evocative image of dunes in transition in desert places. Some others restrict desertification to issues related with erosion and drought. And finally, there are really few people that are able to connect this phenomenon with degradation processes rooted in complex biophysical and human dynamics. This fact shows the existing gap between scientific knowledge generated in our country (one of the most prolific in the matter) and the information and knowledge settled in the popular and institutional collective imagination.

In order to face desertification and to strength the raising awareness and civil action about it, the United Nations Convention to Combat Desertification (UNCCD) has become the main institutional tool to mitigate the problem at the international level. The Convention establishes the internationally agreed definition of desertification. Most of the communication, education and public awareness actions concerning land degradation are also coordinated under the UNCCD umbrella. For instance, in 2003, at the 58° session of the United Nations General Assembly (UNGA), 2006 was acknowledged as the International Year of the Deserts and the Desertification. One year later, in 2007, the UNGA declared the period 2010-2020, as the Decade for Deserts and the Fight Against Desertification. Specifically, the UNCCD has established the period 2008-2018, as temporary horizon, to strengthen the implementation of the Convention through the Decennial Strategy.

The present work lines up with several of the operational objectives of the Decennial Strategy. Mainly with those objectives direct and indirectly related to desertification knowledge and sustainable land management. That is because generation, conservation, management and transmission of traditional and scientific knowledge concerning desertification, is one of social components of the phenomenon most neglected from the scientific arena.

The first part of the work introduces the formal elements of the thesis: the theoretical framework, the objectives and a generic description of the methodology. In the second part, the results compiled in eight scientific publications are presented and discussed. Finally, the third part summarizes the general conclusions and some contributions of the thesis.

From a conceptual point of view, "Manejo del suelo y desertificación: entre la ciencia y la praxis" proposes a progressive approach. The drivers and socio-economic processes involved in land degradation in Spain are analyzed in chapter four, the first chapter of results, approaching the push-pull dynamics that promotes land use changes from agriculture to urban sprawl.

Later in the dissertation, desertification technical approaches are studied through the bibliometric analysis of the scientific international literature relating to the phenomenon. These analyses are developed at the global arena (chapter five) and across two specific case studies: Spain (chapter six) and Argentina (chapter seven). The revision of the scientific international literature published in Spain and Argentina became particularly interesting attending to the differences and concurrences of the ecological, economic and cultural conditions of both countries.

The last results chapters return to the national arena focusing on soil knowledge and analyzing the overlaps and gaps between soil science and soil management in the central region of Spain.

The eighth chapter compares the know-why scientifically generated and the know-how implemented by the farmers in the agrarian district of Las Vegas. Las Vegas is an especially dynamic region located in the peri-urban area of one of the principal economic centers of the country (Madrid). This area it is also interesting due to the strong effects of urban development and socioeconomic conflicts that hinder agrarian development.

Chapters nine and ten analyze the perceptions of vine-growers and olive growers from the central region of the country about the use of sustainable land management technologies devoted to erosion control, such as: cover crops, minimum tillage or contour tillage practices. These chapters illustrate the benefits and constraints of different types of cover crops (chapter ten) and the factors that condition the acceptance or rejection of this type of technologies by the land users (chapter nine).

Finally chapter 11 compares scientific know-why and traditional know-how when assessing the quality of more than 60 farm plots from 31 different farmers. The factors influencing the similarities and dissimilarities between both kinds of knowledge are also analyzed.

Along the work several contributions towards the study of desertification have arisen. Some of them are interesting in order to promote communication, education and public awareness about the issue. Some others would be useful to reinforce the research about socioeconomic matters concerning desertification as well as to improve the methodologies traditionally implemented in soil sciences. The main contributions of this thesis to the field of land degradation research are:

1.-The development of a theoretical model on the push-pull dynamics of desertification in Spain. It is a concise, easily communicable and proximate model to multiple stakeholders. For instance, this model is very illustrative for farmers. They are affected by the Common Agricultural Policy and the agrarian market fluctuations, but during the real-estate boom they also suffered labor shortage for its escape to the urban sector and were seduced by the opportunities of requalification and purchase of agrarian plots.

2.-The bibliometric analysis of the scientific literature regarding to soil has allowed identifying two theoretical approximations clearly separated: the soil approach and the land approach.

Both approaches must join equitably in any advisory panel on soil degradation. This conclusion should be considered by the UNCCD.

The detailed bibliometric analysis of the Spanish and the Argentinean case studies has demonstrated the need to advance in the development of the land approach versus the soil approach, nowadays dominant. These works have also revealed the need to reinforce the integration of socioeconomic issues in the soil research, if science expects to effectively contribute to the search of local solutions to combat desertification.

3. - In the Autonomous Community of Madrid, a preliminary assessment of the overlaps and gaps between scientific and agrarian traditional knowledge has been developed regarding to physical-chemical characterization of soils and also about the acceptance of sustainable land management practices by land users .

The results of this exercise can be very useful to guide the training programs coordinated from the agrarian transfer services and to design strategies of agro-environmental awareness. This first approximation opens the door for new lines of research aligned with the difficulties that land users frequently face when dealing with the balance between profitability and sustainability.

As general conclusions it deserves to be mentioned the urgent need to strength the political will and the economic resources devoted to support the sharing experience among formal and informal knowledge developers and land users. The education and awareness rising about the human causes of desertification should also be promoted from the public institutions.

The definition and implementation of specific measures to control the main drivers of the push pull dynamics of land use change from agrarian uses to urbanization are also needed to be addressed.

These and other contributions of the thesis are discussed in the chapter devoted to conclusions.

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Listado de acrónimos

AKIS, Agricultural Knowledge and Innovation Systems

CILSS siglas en inglés, Comité Interestatal Permanente para el Control de la Sequía en el Sahel

CM, Comunidad de Madrid

COP siglas en inglés, Conferencia de las Partes

COP8 siglas en inglés, 8º Conferencia de las Partes

DPSIR, Driving Forces-Pressures-States-Impacts-Responses

EEA, European Environmental Agency

ES, Ecosystem Service

EU, European Union

FAO, Food and Agriculture Organization of the United Nations

GDP, Gross Domestic Product

GLADA, Global Assessment of degradation and improvement

GLADIS, Global Land Degradation Information System

GLASOD, Global Assessment of Human-Induced Soil Degradation

ICASALS, International Centre for Arid and Semi-Arid Land Studies

IMIDRA, Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario

INIA, Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria

IPBES siglas en inglés, Plataforma Intergubernamental sobre Biodiversidad y Servicios Ecosistémicos

IPCC siglas en inglés, Panel Intergubernamental de Cambio Climático

ISSS, International Society of Soil Science

JCR, Journal Citation Reports

JRC EC, Joint Research Center European Commission

LADA, Land Degradation Assessment in Drylands

LUS, Land Use System

MAGRAMA, Ministerio de Agricultura, Alimentación y Medio Ambiente

MAPA, Ministerio de Agricultura, Pesca y Alimentación

MMAMRM, Ministerio de Medio Ambiente, Medio Rural y Marino

NDVI, Normalized Difference Vegetation Indices

OCDE, Organización para la Cooperación y el Desarrollo Económicos

PAC, Política Agraria Común

PAND, Programa de Acción Nacional Contra la Desertificación

PCA, Principal Component Analysis

SCAR, Standing Committee on Agricultural Research

SD, Statistical Deviation

SDI, Index of sensitivity to desertification

SIGA, Sistema de Información Geográfica de Datos Agrarios

SLA, Sustainable Livelihood Approach

SLM siglas en inglés, Manejo Sostenible de la Tierra

SOC, Soil Organic Carbon

SOTER, Soil and terrain digital database

UNCCD siglas en inglés, Convención de Naciones Unidas de Lucha Contra la Desertificación

UNCED siglas en inglés, Conferencia de Medio Ambiente y Desarrollo

UNCOD siglas en inglés, Conferencia de Desertificación de Naciones Unidas.

UNEP siglas en inglés, Programa de Naciones Unidas para el Medio Ambiente

UNESCO siglas en inglés, Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura

UNGA siglas en inglés, Asamblea General de Naciones Unidas

USLE, Universal Soil Loss Equation

WMO, World Meteorological Organization

WOCAT, World Overview of Conservation Approaches and Technologies

Listado de artículos compilados

La tesis “Manejo del suelo y desertificación: entre la ciencia y la praxis” se presenta como compilación de artículos enviados a revistas indexadas en el Journal Citation Reports (JCR) de Web of Science. A continuación se detalla el título de cada trabajo y la situación en la que se encuentra:

- Capítulo 4. Barbero-Sierra C, Marques MJ y Ruíz-Pérez M. (2013). The case of urban sprawl in Spain as an active and irreversible driving force for desertification. *Journal of Arid Environments* 90: 95-102: doi:http://dx.doi.org/10.1016/j.jaridenv.2012.10.014.

- Capítulo 5. Escadafal R, Barbero-Sierra C, Exbrayat W, Marques MJ, Akhtar-Schuster M, Haddadi AE, Ruíz, M. (2015). First appraisal of the current structure of research on land and soil degradation as evidenced by bibliometric analysis of publications on desertification. *Land Degradation & Development* 26: 413-422: doi: 10.1002/ldr.2351.

- Capítulo 6. Barbero-Sierra C, Marques MJ, Ruiz M, Escadafal R y Exbrayat W. (2015). How desertification research is addressed in Spain? Land versus Soil approaches. *Land Degradation & Development* 26: 423-432 doi:10.1002/ldr.2344.

- Capítulo 7. Torres L, Abraham EM, Rubio C, Barbero-Sierra C y Ruiz-Pérez M. (2015). Desertification research in Argentina. *Land Degradation & Development* 26: 433-440: doi:10.1002/ldr.2392.

- Capítulo 8. Barbero-Sierra C, Marques MJ, Ruíz-Pérez M, Bienes R, Cruz-Maceín JL. (En revisión). Farmers’ soil knowledge, perception and management in Las Vegas agricultural district, Madrid, Spain. Enviado a *Society & Natural Resources*.

- Capítulo 9. Marques MJ, Bienes R, Cuadrado J, Ruiz-Colmenero M, Barbero-Sierra C y Velasco A. (2015). Analysing perceptions attitudes and responses of winegrowers about sustainable land management in central Spain. *Land Degradation & Development* 26: 458-467: doi:10.1002/ldr.2355.

- Capítulo 10. Sastre B, Barbero-Sierra C, Bienes R, Marques MJ, García-Díaz A. (En revisión). Soil loss in an olive grove of central Spain under cover crops and tillage and farmers’ perception. Enviado a *Soil and Tillage Research*.

- Capítulo 11. Barbero-Sierra C, Ruiz-Perez M, Marques MJ. (Manuscrito en preparación). Farmers and soil science criteria assessing plots quality in Las Vegas agrarian district (SE Madrid, Spain). Manuscrito en preparación *Agriculture, Ecosystems and Environment.*

PARTE I

Antecedentes, objetivos y metodología

1. Antecedentes

1.1. LA HISTORIA DE UN MITO MUY REAL O DE CÓMO SUBSISTIR SIENDO LA HERMANA POBRE

1.1.1. La Convención de Naciones Unidas de Lucha Contra la Desertificación

La "Convención de Naciones Unidas de Lucha Contra la Desertificación en los países afectados por Sequía Grave o Desertificación, en particular en África", es el principal referente institucional internacional en materia de lucha contra la desertificación. Al igual que la Convención de Cambio Climático y el Convenio de Diversidad Biológica, surgió a partir de la Conferencia de Medio Ambiente y Desarrollo de Río de Janeiro (UNCED, siglas en inglés) (1992) y las tres hacen parte de las denominadas "Convenciones de Río".

Sus antecedentes inmediatos son la Conferencia de Desertificación de Naciones Unidas (UNCOD, siglas en inglés) celebrada en 1977 en Nairobi y el Plan de Acción de Lucha Contra la Desertificación. Ambas iniciativas surgieron como respuesta a las consecuencias de las sequías reiteradas en la región Sudán-Sahel. Son medidas más globales y posteriores a otros procesos de calado regional, como la constitución en 1973 del Comité Interestatal Permanente para el Control de la Sequía en el Sahel (CILSS, siglas en inglés) y la consolidación en 1976 del Club de Sahel, en el que países de la zona y miembros de la Organización para la Cooperación y el Desarrollo Económicos (OCDE) se asociaron para apoyar al CILSS e incrementar los fondos de ayuda oficial al desarrollo destinados a la región.

Desde el inicio de la década de los setenta la comunidad internacional es consciente de que la desertificación es un problema que amenaza el bienestar económico, social y ambiental de las poblaciones afectadas. Pero no es hasta la Conferencia de Río, cuando se adopta un enfoque centrado en la acción para la mitigación y el desarrollo sostenible y se supera la mera canalización de ayuda económica internacional para paliar los efectos.

Tras la UNCED, en diciembre de 1992, la Asamblea General de Naciones Unidas a través de la resolución 47/188 (UNGA, 1992) estableció un comité para la negociación de la UNCCD. El comité concluyó su misión en cinco encuentros, naciendo así en Junio de 1994 la Convención de Naciones Unidas de Lucha Contra la Desertificación. La Convención entró en vigor el 26 de diciembre de 1996, 90 días después de recibir la quincuagésima ratificación. Desde entonces hasta la fecha, 194 Estados más la Unión Europea, han ratificado la Convención, convirtiéndose así en Partes de la misma.

Entre los hitos históricos del Convenio (Figura 1) merece la pena destacar la 8º Conferencia de las Partes (COP8), celebrada en Madrid en 2007, donde se fijó un punto de inflexión al adoptarse la Estrategia Decenal para la Implementación de la Convención (COP8, 2008).

Oct. 2015	COP12 - Ankara
Sept. 2013	COP11 - Windhoek
Oct. 2011	COP10 - Changwon, aprobación de la “Changwon Iniciative”
Sept. 2011	Reunión de Alto Nivel en la Asamblea General de Naciones Unidas en torno a degradación de la tierra, sequía y desertificación
Sept. 2009	COP9 - Buenos Aires y primera conferencia científica de la UNCCD
Sept. 2007	COP8 - Madrid, Adopción de la Estrategia Decenal
2006	Año internacional de los desiertos y la desertificación
Oct. 2005	COP7- Nairobi
Ago-Sept. 2003	COP6 - La Habana, Global Envoromental Facility mecanismo financiero de UNCCD
Ago-Sept. 2002	Conferencia de Desarrollo Sostenible de Johannesburgo
Dic. 2001	COP5 - Ginebra, establecimiento del Comité de Revisión de Implementación de la Convención (CRIC) como órgano subsidiario de la COP
Dic. 2000	COP4 - Bonn, Adopción de declaración de continuidad de la “Iniciativa de Recife”
Nov. 1999	COP3 - Recife, “Iniciativa de Recife”
Ene. 1999	Secretaría de la UNCCD en Bonn
Dic. 1998	COP2- Dakar, consultas sobre la estrategia de la Secretaría de la UNCCD
Oct. 1997	COP1- Roma. Régimen de funcionamiento de la COP y sus órganos subsidiarios. Definición de funciones del Mecanismo Global
Dic. 1996	Entrada en vigor UNCCD
17 de Jun. 1994	Adopción UNCCD
Jun. 1992	UNCED
Sept. 1977	UNCOD

Figura 1: Cronograma de hitos históricos de la UNCCD. Los discos compuestos (morados y verdes) señalan momentos de especial importancia en la evolución de UNCCD, los discos sencillos (verdes) se corresponden con las reuniones bianuales de la Conferencia de las Partes (COP) y los acuerdos más relevantes alcanzados en ellas. Elaboración propia en base a http://www.unccd.int/en/about-the-convention/history/Important-dates/Pages/default.aspx.

La Estrategia 2008-2018, estableció cuatro objetivos prioritarios, que guían la actividad de los actores de la UNCCD a lo largo de este período:

1. Mejorar las condiciones de vida de las poblaciones afectadas.
2. Mejorar las condiciones de los ecosistemas afectados.
3. Generar beneficios globales a través de la implementación efectiva de la UNCCD.
4. Movilizar recursos para la implementación de la Convención, a través del fomento de la colaboración entre actores nacionales e internacionales.

Asimismo, la Estrategia Decenal también define cinco objetivos operacionales (Convención de Lucha Contra la Desertificación, 2007):

1. Influir activamente en los procesos y agentes pertinentes internacionales, nacionales y locales a fin de que se aborden adecuadamente las cuestiones relativas a la desertificación y la degradación de las tierras y a la sequía.
2. Apoyar la creación de entornos propicios para promover soluciones de lucha contra la desertificación y la degradación de las tierras y mitigar los efectos de la sequía.
3. Llegar a ser una autoridad mundial en materia de conocimientos científicos y técnicos sobre la desertificación y la degradación de las tierras y sobre la mitigación de los efectos de la sequía.
4. Determinar y satisfacer las necesidades de fomento de la capacidad para prevenir y revertir la desertificación y la degradación de las tierras y mitigar los efectos de la sequía.
5. Movilizar recursos financieros y tecnológicos nacionales, bilaterales y multilaterales y mejorar la elección de los beneficiarios y la coordinación de esos recursos a fin de aumentar su impacto y eficacia.

El presente trabajo se vincula estrechamente con los objetivos 1, 2 y 4 de la Estrategia Decenal.

La UNCCD, presenta algunas particularidades respecto a sus hermanas, las convenciones de cambio climático y diversidad biológica, que han llevado a que se la considere la “Cenicienta” de las “Convenciones de Río” (Grainger et al., 2000).

La consideración de la desertificación como un problema local, vigente principalmente en países empobrecidos, dio lugar desde el inicio, al desinterés por parte de los países desarrollados (principalmente Unión Europea y Estados Unidos) y a una polarización Norte-Sur de las negociaciones (Najam, 2006). La negociación de la UNCCD se instrumentalizó como moneda de cambio para que los países del sur (Agarwal et al., 1999; Corell, 1999), principalmente los países africanos (Crespo Llenes, 2001; Najam, 2006), se enrolaran en las negociaciones de la convención de bosques y no se descolgaran de los procesos subsecuentes a Río 92.

La falta de voluntad política de los países desarrollados, así como las incertidumbres existentes en torno a este fenómeno, incluida la ambigüedad de la propia definición del concepto de desertificación, y el escaso apoyo económico recibido (Juntti y Wilson, 2005; Stringer, 2008) hacen que la UNCCD se considere la hermana pobre de las “Convenciones de Río” (Anju, 1999; Grainger et al., 2000). En contraposición, la UNCCD es más receptiva que sus homólogas a la dinamización de procesos participativos que involucren a las poblaciones afectadas y a representantes de la sociedad civil (Knabe, 2006). Se concede así particular importancia a los conocimientos y prácticas tradicionales de los gestores de la tierra. Esto supone también una gran oportunidad para la colaboración entre los generadores y gestores de conocimiento formal e informal y los tomadores de decisiones, en la búsqueda de medidas eficaces para la mitigación y adaptación a los efectos de la desertificación.

Atendiendo a la vigencia del debate sobre la necesidad de instaurar un panel científico asesor de la UNCCD asimilable al Panel Intergubernamental de Cambio Climático (IPCC, siglas en inglés) o la Plataforma Intergubernamental sobre Biodiversidad y Servicios Ecosistémicos (IPBES, siglas en inglés) (Grainger, 2009a; Thomas et al., 2012). Así como, considerando la sensibilidad de la UNCCD por el saber hacer tradicional y su preocupación acerca de los impactos socio-ambientales sufridos por las poblaciones afectadas, gran parte del presente trabajo se dedica al análisis de la ciencia existente en torno a la componente humana de la desertificación y a la visibilización de la importancia de integrar el saber hacer tradicional y científico para frenar este problema.

1.1.2. Conceptualizando el fenómeno de la desertificación

El concepto de desertificación se ha desarrollado desde las esferas científica y gubernamental, priorizando cada uno de ellas diferentes matices del fenómeno, lo que ha dado lugar a gran diversidad de definiciones y a múltiples controversias en torno a ellas (Glantz y Orlovsky, 1983; Herrmann y Hutchinson, 2005; Rubio y Recatalá, 2006). La ambigüedad acerca de si su origen es natural y/o antrópico y el impacto de la combinación de ambos, es uno de los motivos en los que se ampara la inacción política. Por ello, atender a elementos como la magnitud de escala, los agentes y dinámicas implicadas y el estadio de reversibilidad, son cuestiones clave a la hora de definir la desertificación. Sin embargo no todas las definiciones atienden a estos elementos ni les otorgan pesos específicos diferenciados.

Algunas excavaciones arqueológicas han desvelado que procesos de degradación del suelo como la salinización y el depósito de sedimentos, afectaron a los sistemas de riego de Mesopotamia y que probablemente jugaron un importante papel en el colapso de la civilización Sumeria (Jacobsen y Adams, 1958). Igualmente, la sequía prolongada fue uno de los determinantes del declive del imperio Maya (Kennett et al., 2012). Estas evidencias históricas refuerzan la teoría de Spooner (1989), según la cual el fenómeno de la desertificación viene sucediendo desde la época medieval, la era clásica e incluso el neolítico.

Fue en el siglo V, cuando se realizaron los primeros registros escritos relacionados con procesos de desertificación. El Codex Theodosianus (438 d.c) ya hizo referencia a las *agri deserti* -explotaciones imperiales consideradas poco productivas- y a otras tierras abandonadas por su escasa fertilidad o como consecuencia de campañas militares (Rubio y Recatalá, 2006).

Pero no se enuncia textualmente el concepto de desertificación, hasta las primeras décadas del siglo XX (Verón et al., 2006), cuando en plena expansión colonial en el África Occidental (Adger et al., 2001; Davis, 2004), algunos investigadores y viajeros (ej. Bovill 1921; Stebbing 1935) expresaron su preocupación por los síntomas de degradación del suelo y el avance del desierto del Sáhara (Herrmann y Hutchinson, 2005). Concretamente fue Louis Lavauden, quien por primera vez en 1927, hizo alusión al término, en la publicación *Les Forèts du Sahara* donde menciona "*dans toute la zone … la désertification, si j'ose dire, est purement artificielle. Elle est* *uniquement le fait de l'homme*"[1] (Mainguet y Da Silva, 1998). Es decir, Lavauden vinculaba la desertificación activa en la región exclusivamente con procesos humanos, sin atender a fenómenos ambientales que pudieran facilitar los procesos de degradación.

En el ámbito científico, para muchos autores, el padre del término es Andre Aubréville (Glantz y Orlovsky, 1983), quien en 1949 en el informe titulado *Climats, Forêts et Désertification,* comenta "*Ce sont de vrais déserts qui naissent aujourd'hui sous nos yeux, dans des pays oú il tombe annuellement de 700 à plus de 1500 mm de pluies*";[2][3] (Mainguet y Da Silva, 1998).

Las alusiones al fenómeno de la desertificación en estas dos primeras aproximaciones al concepto, resaltan el factor humano como causante, el carácter de proceso activo y visibilizan la diversidad de condiciones climatológicas en las que se pueden producir fenómenos de desertificación. En cambio, la conceptualización de la desertificación ha evolucionado hacia enfoques más complejos en algunos aspectos (incorporando los factores naturales y la importancia de la combinación de agentes naturales y antrópicos) y reduccionistas en otros (limitando la localización geográfica a zonas áridas, semiáridas y sub-húmedas secas).

A lo largo de las décadas de los cincuenta[4], sesenta[5] y setenta[6], fue surgiendo en los entornos institucional, científico y ciudadano una creciente concienciación sobre la vinculación entre los procesos ambientales y sociales (Mainguet, 2003). Así mismo los dramáticos impactos de las sequías y las consecuentes hambrunas en África a lo largo del período 1968-1972 (Figura 2), contribuyeron a la celebración de la Conferencia de Naciones Unidas sobre el Medio Humano (Mainguet, 2003), que sembró la semilla para la discusión internacional sobre los principales fenómenos socio-ambientales globales. Este debate germinaría en la Conferencia de Río de 1992.

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[1] "a lo largo de la región... - me atrevo a decir- que la desertificación es puramente artificial: únicamente causada por el hombre".

[2] "Actualmente están surgiendo desiertos ante nuestros ojos, en regiones donde el rango de precipitación anual alcanza los 700-1500mm".

[3] Estos rangos de precipitación son notablemente superiores a los registrados en las zonas áridas, semiáridas y subhúmedas secas en las cuales los rangos de precipitación oscilan entre 100 y 800 mm/año (FAO, 1989).

[4] En 1950 la organización de Naciones Unidas para la Educación, la Ciencia y la Cultura (UNESCO, siglas en inglés) lanzó un programa de investigación específico sobre las regiones áridas (*Arid Zones Research Program*) (Verstraete, 1986).

[5] En 1960 bajo el amparo de Naciones Unidas, más de 200 centros de investigación publicaron el primer análisis científico con un carácter eminentemente ambiental en torno a las zonas áridas. Por su parte, Rachel Carson en 1962 denunció en *Silent Spring* (Carson, 1962), los nefastos efectos de la agricultura industrializada y la contaminación y consiguió captar la atención de la ciudadanía respecto a estos problemas.

[6] En 1972, el informe del Limits to Growth (Meadows et al., 1972) marcó un punto de inflexión en la comprensión de la interdependencia entre el bienestar humano y ecosistémico.


ABC
REPORTAJ

La región saheliana —al sur del Sahara— no sólo necesita ayudas para salir de la actual crisis, sino para evitar que catástrofes como la actual puedan repetirse. Los técnicos están muy preocupados ante el avance de la arena del desierto y por el gran número de ganado desaparecido.

LOS tres mil kilómetros de franja saheliana que limitan con el Sahara siguen sufriendo los efectos de la sequía que ha aniquilado a más de cuatro millones de cabezas de ganado. Los primeros síntomas del gran horror que se avecina fueron detectados hace trece meses, pero el hombre del Sahel no llamó la atención del mundo desde el principio. No entraba en sus costumbres pregonar a los vientos la tragedia que se le avecinaba.

Los seis países que sufren la catastrófica sequía —Mauritania, Senegal, Mali, Alto Volta, Niger y Chad—, los hombres de esos seis países, contaron primero con su propio esfuerzo para vencer el grave problema que se predecía; contaron con su propio esfuerzo nacional pues, opinan, «es en Africa donde en primer término hemos de buscar las soluciones a nuestros problemas».

Y así lo hicieron, pero la gravedad del caso se escapó a sus posibilidades de solución y así el presidente de Alto Volta dio a conocer al mundo el problema a finales de año, después de soportar tres largos meses de esperanzas.

Pero la lluvia no llegaba; los pastos se agotaban y el pánico comenzaba a cundir entre los rudos hombres del Sahel. Entonces las autoridades de los seis países hermanos pensaron que tenían derecho a recibir la colaboración de los países desarrollados y de las organizaciones internacionales del desarrollo.

● Llega la primera ayuda

De ese modo una avalancha de ayudas comenzó a llegar a Ouagadougou, aun sin que las autoridades africanas tuvieran dispuesto el mecanismo de recepcion. Primero fueron las Naciones Unidas a través de la F. A. O. y del Programa Mundial de Alimentos; luego fue la Comunidad Económica Europea y los Gobiernos de Canadá, Estados Unidos, Alemania, Bélgica, Francia y España. Se trataba de ayudas de primera necesidad que podían hacer que los damnifica-

Figura 2: Noticia sobre los efectos de la sequía en la zona de Sahel fechada en 1973. Fuente: ABC Madrid (Pág. 123 edición 18/19/1973)

Previamente, en 1977, preocupados igualmente por los estragos de las sequías en África, la UNGA aprobó la celebración en septiembre de ese mismo año de la UNCOD. En esta conferencia surgió un primer Plan de Acción Contra la Desertificación y la primera caracterización oficial internacional del fenómeno de la desertificación (Artículo 7 UNCOD, 1978):

"*La desertificación es la disminución o destrucción del potencial biológico de la tierra, y puede conducir en última instancia a condiciones desérticas. Es una componente del deterioro generalizado de los ecosistemas, y ha disminuido o destruido el potencial biológico, es decir, la producción vegetal y animal, para múltiples propósitos de uso, en un momento en que se necesita una mayor productividad para sustentar a las poblaciones en crecimiento y promover el desarrollo. Algunos factores importantes en la sociedad contemporánea - la promoción del desarrollo y el esfuerzo para aumentar la producción de alimentos, y para adaptar y aplicar tecnologías modernas, en un contexto de crecimiento poblacional y de cambio demográfico – se entrelazan en una red de causas y efectos. El avance del desarrollo, el crecimiento demográfico planificado y la mejora en todos los tipos de producción biológica, así como la adopción de tecnologías pertinentes deben integrarse. El deterioro de los ecosistemas productivos es una amenaza evidente y grave para el progreso humano. En general, la búsqueda de mayor productividad ha intensificado la explotación y ha llevado a la intervención humana en las tierras menos productivas y más frágiles. La sobreexplotación da lugar a la degradación de la vegetación, el suelo y el agua, los tres elementos que sirven de base natural para la existencia humana. En los ecosistemas excepcionalmente frágiles, como son los márgenes de los desiertos, la pérdida de la productividad biológica a través de la degradación de los recursos vegetales, animales, suelo y agua pueden fácilmente convertirse en irreversibles, y reducir permanentemente su capacidad para sustentar la vida humana. La desertificación es un proceso de auto-aceleración, que se retroalimenta a sí mismo, y a medida que avanza, los costos de rehabilitación se incrementan exponencialmente. Se requiere actuar con urgencia para combatir la desertificación, antes de que los costos de rehabilitación se incrementen por encima de las posibilidades prácticas o antes de que la oportunidad de actuar se pierda para siempre*"

Esta definición del fenómeno destaca la pérdida de productividad y sus impactos en el bienestar humano, así como al carácter antrópico, el coste económico y la reversibilidad del problema. Por otra parte alude en términos generales a tierras y ecosistemas frágiles sin restringir la desertificación necesariamente a determinadas regiones climáticas.

En los siguientes años los esfuerzos se centraron en el desarrollo del Plan de Acción contra la Desertificación y desde la ciencia se trabajó en la caracterización de la cuestión (Hellden, 1991). En la década de los noventa, el Programa de Naciones Unidas para el Medio Ambiente (UNEP, siglas en inglés) propone como base para su discusión en la Conferencia de Río: "Desertificación es la degradación de la tierra en zonas áridas, semiáridas y subhúmedas secas, como resultado básicamente de conductas humanas adversas" (UNEP, 1991). Esta definición destaca la responsabilidad antrópica como origen y restringe los territorios vulnerables en función de parámetros climáticos.

En 1992 en la UNCED, tras una fuerte presión por parte de los países africanos (Adger et al., 2001; Najam, 2006), se estableció el Comité Intergubernamental para la Negociación de la Convención sobre Desertificación (UNGA, 1992). Finalmente, el 17 de Junio de 1994 se adoptó en París la "*Convención de Naciones Unidas de Lucha Contra la Desertificación en los Países afectados por Sequía Grave o Desertificación, en particular en África*", que establece la definición que definitivamente se consolidaría internacionalmente: "Desertificación es la degradación de la tierra en zonas áridas, semiáridas y subhúmedas secas debido a varios factores, que incluyen las variaciones climáticas y las actividades humanas" (Artículo 1 a., UNGA, 1994).

En esta definición, la expresión degradación de la tierra hace alusión a: "*La reducción o la pérdida de la productividad biológica o económica y la complejidad de las tierras agrícolas de secano, las tierras de cultivo de regadío o las dehesas, los pastizales, los bosques y las tierras arboladas, ocasionada, en zonas áridas, semiáridas y subhúmedas secas, por los sistemas de* *utilización de la tierra o por un proceso o una combinación de procesos, incluidos los resultantes de actividades humanas y pautas de poblamiento*" (Artículo 1 f., UNGA, 1994). Ejemplos concretos de este tipo de degradación serían:

(i) la erosión del suelo causada por el viento o el agua,
(ii) el deterioro de las propiedades físicas, químicas y biológicas o de las propiedades económicas del suelo, y
(iii) la pérdida duradera de vegetación natural.

Por su parte, las zonas áridas, semiáridas o subhúmedas, son todas aquellas zonas en las que la proporción entre la precipitación anual y la evapotranspiración potencial está comprendida entre 0,05 y 0,65, excluidas las regiones polares y subpolares (Artículo 1 g., UNGA, 1994).

Esta definición, a pesar de ser la más extendida, presenta algunas lagunas. Por una parte excluye a todos los territorios sometidos a procesos de degradación de la tierra no localizados en zonas secas (Safriel, 2009). Esto induce a que los países afectados por procesos de degradación del suelo y localizados fuera del régimen árido-subhúmedo, no conciban la UNCCD como un marco de referencia y acción para solventar sus problemas de degradación de la tierra.

La definición de desertificación de la UNCCD no clarifica si es un fenómeno global o local (Dregne, 2002; Lambin et al., 2002), lo que facilita la desvinculación de los países no gravemente afectados ya que perciben que es un problema lejano o ajeno a ellos.

Igualmente la formulación del concepto de desertificación asumido por la UNCCD diluye la responsabilidad de la actividad humana en el origen del fenómeno al equipararla a las causas naturales (Le Houérou, 2002). En cierto modo este paralelismo ampara la inacción de muchos actores, que lo perciben como un proceso natural e incontrolable asemejándose a la estrategia de los negacionistas del cambio climático.

Finalmente, esta definición tampoco esclarece si es un proceso o el estadio final de un proceso o conjuntos de procesos (Thomas y Middleton, 1994); no discrimina entre los diferentes grados de degradación existentes y sus causas, mecanismos o consecuencias (Mainguet, 2003; Warren, 2002) y no hace alusión al grado de reversibilidad del fenómeno (Mainguet, 1990). Todo ello dificulta el diseño de estrategias diferenciadas en el caso de que sea un proceso activo, en el que se requiere intervención sobre los agentes causantes, o pasivo, en el que se requieren medidas de recuperación o bien de adaptación si nos encontramos ante un escenario no reversible.

La ambigüedad del concepto (Juntti y Wilson, 2005) derivada de todas estas incertidumbres, ha dado lugar a malas interpretaciones en cuanto a los agentes, procesos, impactos y medidas de acción necesarias para hacer frente a la desertificación (Adger et al., 2001). En algunos casos, esto ha contribuido a la sobreestimación de la extensión del territorio y de población humana afectada por el fenómeno, lo que ha motivado la construcción y arraigo en el imaginario científico, político y popular del "mito de la desertificación" (Binns, 1990; Hellden, 1991; Thomas y Middleton, 1994).

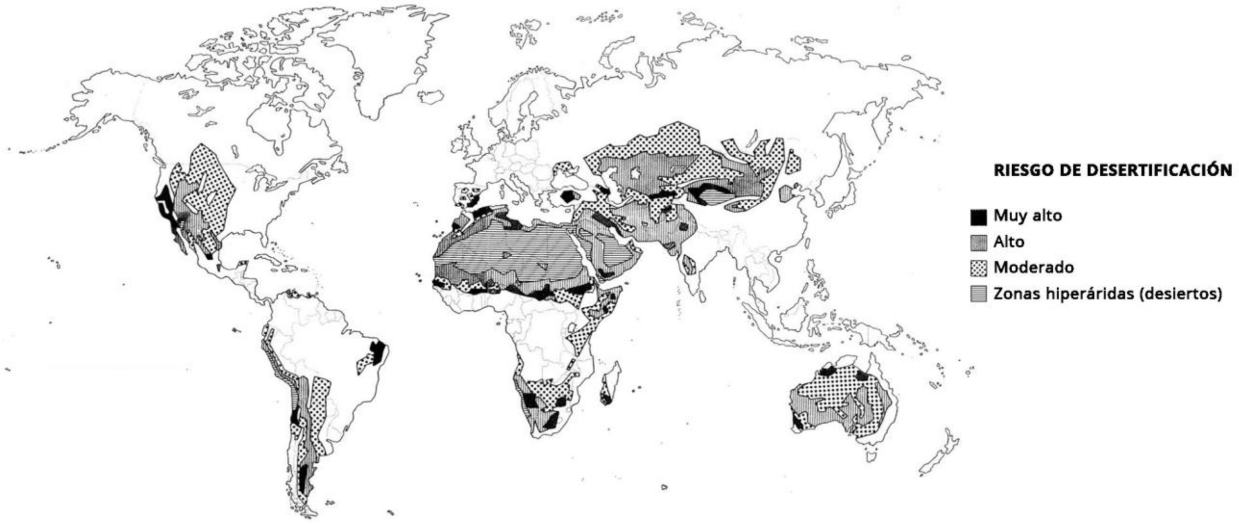
1.1.3. Algunos mitos sobre la desertificación

Extensión y población afectada

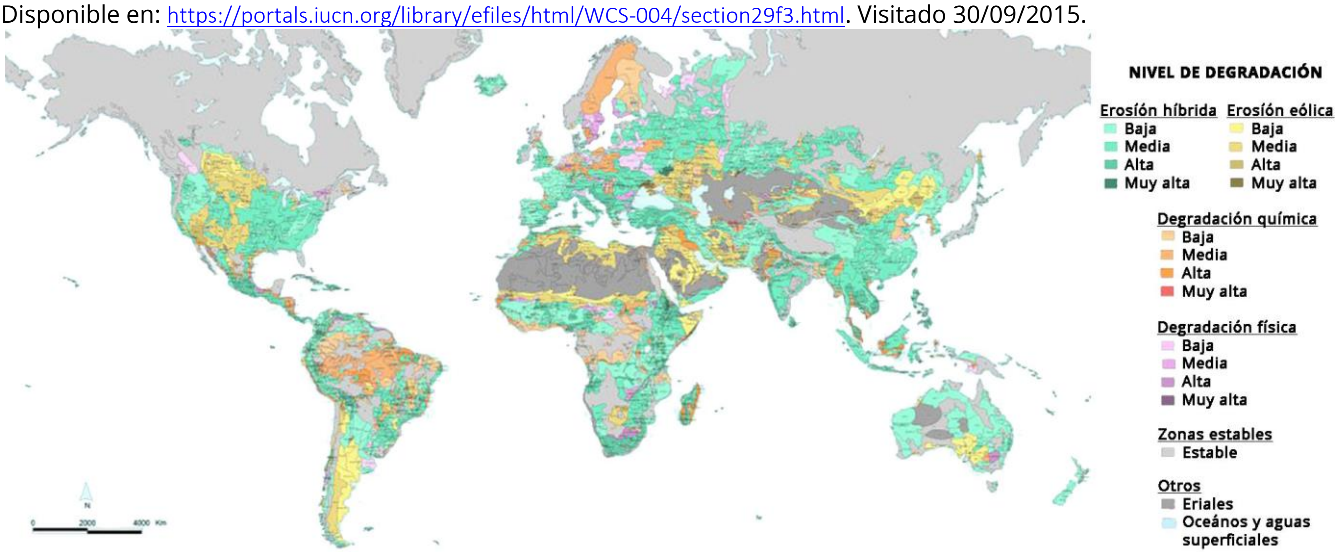
La desertificación ha sido denostada social e institucionalmente, entre otros motivos, por el alto grado de incertidumbre que la rodea. Una de las principales dificultades técnicas, que ha tenido un impacto sustancial en el desarrollo de políticas anti-desertificación, es la determinación de la extensión total y la población humana afectada por este fenómeno.

En cuanto a la delimitación de las áreas afectadas, uno de los primeros ejercicios que se realizó, fue el estudio llevado a cabo por Lamprey en 1975. Este trabajo pretendía evaluar el avance del desierto en la zona Centro-Oeste de Sudán. La frontera de avance del Sahara en la región, fue mapeada a través de reconocimiento aéreo y con apoyo de vehículos terrestres y los resultados obtenidos se compararon con los publicados en 1958 por Harrison y Jackson. Esta comparación concluyó que la frontera sur del desierto del Sahara se había desplazado en torno a 90-100 km entre 1958 y 1975, es decir el desierto había avanzado al vertiginoso ritmo de 5.5 km por año, durante este período.

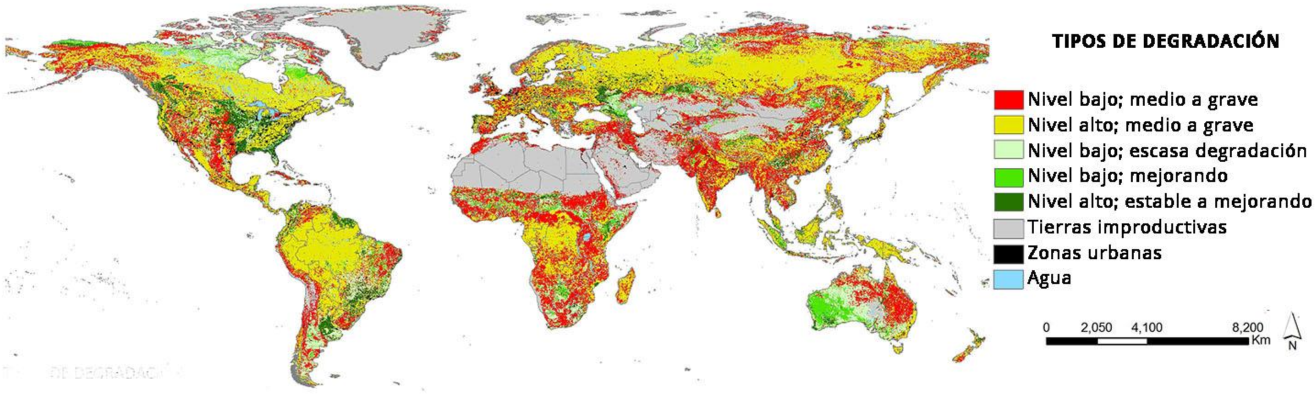
Al igual que ha sucedido con otras crisis socio-ambientales, como es el caso de la crisis de la leña (Sauerhaft et al., 1998), divulgadas en torno a cifras y previsiones alarmistas, en su momento, las conclusiones de Lamprey tuvieron un gran impacto político y consiguieron captar la atención y recursos de las instituciones internacionales (Crespo Llenes, 2001). Sin embargo, estas previsiones fueron calificadas como erróneas (Hellden, 1984; Tucker et al., 1991; Warren y Agnew, 1988) y catastrofistas (Verón et al., 2006) y de hecho, uno de los grandes retos en las esferas internacional y científica, es la consolidación de una cifra técnicamente verosímil respecto a la magnitud de la extensión de territorio sometido a los efectos de la desertificación (Figura 3).



Fuente: Modificado a partir de UNEP, FAO, UNESCO y WMO 1977. *Desertification Map of the World*. Disponible en: https://portals.iucn.org/library/efiles/html/WCS-004/section29f3.html. Visitado 30/09/2015.



Fuente: Modificado a partir de Proyecto GLASOD. *Global Assessment of the Status of Human-Induced Soil Degradation*.1990. Disponible en http://www.isric.org/sites/default/files/glasod_mercator1000.jpg. Visitado 30/09/2015.



Fuente: Modificado a partir de Nachtergaele et al., 2011.Global Land Degradation Information System (GLADIS) version 0.5. An Information database for Land Degradation Assessment at Global Level.

Figura 3: Mapas de desertificación de UNCOD en 1977, el proyecto GLASOD en 1990 y el proyecto LADA en 2010.

En este sentido, el UNEP lideró en 1976-1977, 1983-1984 y 1991-1992, sendas iniciativas globales para la evaluación de la desertificación. Los resultados de estas campañas (Tabla 1) a pesar de ser ampliamente difundidos, han sido muy criticados por su veracidad científica. Debido a las metodologías y medios disponibles, fueron pocos los datos reales que se trataron (principalmente en los dos primeros casos: 1976-1977 y 1983-1984) y casi todos los resultados son estimaciones basadas en el conocimiento de expertos, susceptibles a cierto grado de subjetividad (Agnew y Warren, 1990; Thomas y Middleton, 1994).

Posteriormente, entre 2006 y 2010, UNEP y FAO promovieron el proyecto *Land Degradation Assessment in Drylands* (LADA). Este proyecto se destinó al desarrollo e implementación de tecnologías para la evaluación de la degradación del territorio en zonas secas y al fortalecimiento de capacidades en los entornos nacional, regional y global para mitigar la degradación de la tierra y establecer estrategias sostenibles de uso y manejo (UNEP y FAO, 2011). Esta iniciativa ha dado lugar a un amplio sistema de información (GLADIS)[7] y a numerosas herramientas destinadas a la evaluación de la degradación de la tierra a escala regional, nacional y global. Estas herramientas prestan atención a la combinación de factores biofísicos y sociales, lo que supone un valor añadido frente a las iniciativas anteriores de UNEP.

Las tierras secas ocupan un 41% de la superficie emergida del planeta y se estima que entre un 4% y un 74% de las mismas están afectada por procesos de degradación, siendo el porcentaje de degradación más frecuentemente citado en torno al 70% (Safriel, 2007). Las estimaciones espaciales señaladas en la Tabla 1, si bien no son tan pronunciadas, oscilan entre 3900 y 3500 millones de hectáreas. Las estimaciones más conservadoras coinciden con los ejercicios más recientes, en los que se ha contado con mejores medios técnicos y por tanto se han podido ajustar mejor los márgenes de error.

Una tendencia inversa se detecta en las previsiones referentes a la población afectada. En las estimaciones iniciales, la población vulnerable rondaba los 630 millones de personas, en cambio las predicciones del proyecto LADA incrementan esta cifra a más del doble, alcanzando los 1500 millones. Este sustancial incremento responde a las dinámicas demográficas mundiales, especialmente vertiginosas en los países en desarrollo y concretamente en África. Pero también puede reflejar el potencial de la desertificación como detonante para la migración interna e internacional (Osterwalder, 2011; Requier-Desjardins, 2008; UNCCD, 2014) y su consecuente impacto en poblaciones no directamente afectadas por la desertificación.

En definitiva, para evaluar la magnitud territorial y poblacional del avance de la desertificación es necesario abordar el fenómeno desde el punto de vista espacial, temporal, económico, ambiental y cultural (Warren, 2002). No obstante, estas aproximaciones interdisciplinares topan con múltiples dificultades (Vogt et al., 2011). Además ninguna evaluación será concluyente o definitiva puesto que la desertificación es un fenómeno dinámico (Warren, 2002) en cuyo estudio es importante considerar la cuestión de escala, pero también la naturaleza de los agentes antrópicos que la provocan, su vigencia y el escenario final en el que desembocará el proceso.

[7]Accesible en: http://www.fao.org/nr/lada/?lang=es

Tabla 1. Estimaciones sobre la extensión global y la población total afectada por la desertificación. Elaboración propia en base a: Bai et al., (2008); Eswaran et al., (2001); Kellner et al., (2011); Oldeman et al., (1990); Rubio y Recatalá, (2006); Thomas y Middleton, (1994); UNCOD, (1978) y UNEP y FAO, (2011).

INICIATIVAS	1976-1977 UNCOD	1983-1984 General Assessment of Progress	1991-1992 General Assessment of Progress II	2006-2010 LADA project
PRODUCTOS	World Map of Desertification Risk. FAO, UNESCO y WMO	World Map of Desertification Hazards of the African Continent. FAO, UNEP, UNESCO, WMO	World Map of the Status of Human-Induced Soil Degradation. ISRIC, UNEP World Atlas of Desertification. UNEP	Global Land Degradation Information System (GLADIS)
METODOLOGÍAS IMPLEMENTADAS	• Estimaciones • Mapas (Mapas de aridez; Mapas de suelos; Mapas de vegetación, etc.)	• Cuestionarios a 91 países • Estudios de expertos (Dregne, 1983; Mabbutt, 1984)	• Base de datos Global Assessment of Human-Induced Soil Degradation (GLASOD) • Colaboración con el International Centre for Arid and Semi-Arid Land Studies (ICASALS)	• Bases de datos Global Assessment of degradation and improvement (GLADA) = GLASOD + Normalized Difference Vegetation Indices (NDVI) + Soil and terrain digital database (SOTER) • Clasificación Land Use System (LUS) • Imágenes satélite • Evaluaciones participativas • Cuestionarios "Questionnaire for Mapping Land Degradation and Sustainable Land Management" • Base de datos World Overview of Conservation Approaches and Technologies (WOCAT) • Enfoques: Driving forces, Pressures, States, Impacts, and Responses (DPSIR); Ecosystem Service (ES) y Sustainable Livelihood Approach (SLA) • Visitas de campo
ZONAS CLIMÁTICAS	Áridas, semiáridas y subhúmedas	Áridas, semiáridas y subhúmedas	Áridas, semiáridas y subhúmedas secas	Áridas, semiáridas y subhúmedas

(Cont.)

INICIATIVAS	1976-1977 UNCOD	1983-1984 General Assessment of Progress	1991-1992 General Assessment of Progress II	2006-2010 LADA project
SUPERFICIE AFECTADA (MILLONES DE HECTÁREAS)	**3970**	**3475**	**3592**	**3506**
POBLACIÓN AFECTADA (MILLONES DE PERSONAS)	**628**	**850**	**2600**[8]	**1538**

[8] Estimación basada en el trabajo de Eswaran et al., (2001) partiendo del Mapa Mundial de Suelos (FAO, 1991) y el mapa de densidad de población de Tobler et al., (1995).

¿Es la desertificación un fenómeno local o global?

En el análisis de la desertificación la cuestión de escala importa (Lambin et al., 2002). El estudio a escala local e incluso nacional ha demostrado la importancia biofísica y socio-ecológica de la desertificación, pero este tipo de aproximaciones a escala global no son tan frecuentes (Geist y Lambin, 2004).

El carácter multidisciplinar (ya que alude a cuestiones ambientales, sociales y económicas) y multiescalar (en los ámbitos geográfico e institucional) de la desertificación, unido a la falta de información y la ambigüedad de la propia definición ha dado lugar, sobre todo en los países desarrollados, al calado de la idea de que la desertificación es un fenómeno ajeno (Rubio y Recatalá, 2006), sobre el cual la población no afectada es incluso un tanto escéptica (Dregne, 1995; Verón et al., 2006).

Esta postura se confronta con la naturaleza global de algunos de los agentes causantes de la desertificación (ej. clima, suelo, patrones hidrológicos, dinámicas poblacionales, políticas agrarias y comerciales) y que en climas fuera del rango árido-subhúmedo seco son igualmente causantes de degradación del suelo. Por otro lado, gran parte de las decisiones políticas e institucionales en torno al fenómeno derivan también de acuerdos internacionales (Lambin et al., 2002), pero su implementación local, regional y estatal depende en gran medida de la voluntad política de las instituciones subnacionales.

Por todo ello, la aproximación del presente trabajo, parte de la premisa que si bien el fenómeno de la desertificación se hace tangible a mediana o pequeña escala (Reynolds et al., 2003), por sus consecuencias socio-ambientales y por la naturaleza de los agentes que la provocan, es un problema de escala global, que sobrepasa los límites naturales de las zonas áridas, semiáridas y subhúmedas secas y no entiende de fronteras políticas o administrativas. Por tanto, como sucede en muchos otros trabajos (Nkonya et al., 2011), emplearemos indistintamente los términos degradación de la tierra y desertificación, sin adscribir este último exclusivamente a las zonas áridas, semiáridas y subhúmedas secas, sino centrando la atención en la naturaleza de los factores que están originando la degradación del sistema.

Causas y consecuencias

El carácter multifactorial de la desertificación es otro de los elementos que dificulta su comprensión y contribuye a la imagen de mito. Existe una extensa bibliografía en cuanto a la identificación y clasificación de los agentes causales y los impactos derivados de la desertificación. No obstante, la capacidad degradadora de cada agente y la intensidad de los impactos generados puede ser muy variable atendiendo a la realidad económica y social del área en el que se manifiesten y a la combinación de uno o varios factores en el proceso o a la retroalimentación entre ellos (Geist y Lambin, 2004). La Tabla 2 presenta un resumen de las principales causas e impactos de la desertificación, atendiendo a su escala de acción:

Tabla 2. Agentes causantes e impactos de la desertificación, clasificados según su escala. Elaboración propia a partir de Geist y Lambin (2004); Mainguet y Da Silva (1998); Millenium Ecosystem Assessment (2005); Nkonya et al., (2011); Olanrewaju y Koala (2003); Reynolds et al., (2005); Rubio y Recatalá (2006); Stringer et al., (2011); Thomas y Middleton (1994).

AGENTES CAUSANTES	GLOBAL	REGIONAL	LOCAL
Comercio internacional, volatilidad de precios	X	X	X
Dinámicas demográficas: crecimiento poblacional, incremento de la densidad de población, migraciones	X	X	X
Factores climáticos: incremento de la aridez, variación del régimen de lluvias, sequías	X	X	X
Industrialización	X	X	X
Políticas institucionales: desarrollo, cambios de uso del suelo, agrarias, etc.	X	X	X
Urbanización	X	X	X
Conflictos armados	X	X	X
Explotación forestal		X	X
Factores culturales: actitudes, valores y creencias en torno al suelo y el agua		X	X
Fuegos provocados y accidentales		X	X
Infraestructuras		X	X
Inseguridad en la tenencia de la tierra		X	X
Actividades agrícolas y ganaderas: sobreexplotación, sistemas de riego inapropiados			X
Mecanización agrícola			X
Topografía			X
IMPACTOS	GLOBAL	REGIONAL	LOCAL
Degradación del paisaje: transformación de áreas naturales en artificiales	X	X	X
Degradación y/agotamiento de aguas superficiales y subterráneas: colmatación de lagos, contaminación, salinización	X	X	X
Migraciones forzadas	X	X	X
Pérdida de biodiversidad	X	X	X
Pérdida de conocimientos tradicionales	X	X	X
Problemas de seguridad alimentaria	X	X	X
Empobrecimiento: pérdida de oportunidades para la diversificación de ingresos		X	X
Pérdida de cubierta vegetal: cambio de usos, fuegos		X	X
Problemas sanitarios derivados de la falta de agua de calidad, la contaminación del aire por partículas, etc.		X	X
Degradación física y/o química del suelo			X

La importancia del factor humano

La dispar importancia atribuida a los factores antrópicos en las diferentes definiciones de desertificación ha contribuido a crear confusión y a alimentar una cierta visión de la desertificación como mito.

La componente biofísica determina la capacidad de resiliencia de los ecosistemas y el potencial degradador de la desertificación para intervenciones humanas equivalentes. Los efectos de las variaciones climáticas en la aridez y la disponibilidad de agua son ampliamente reconocidos (Cowie et al., 2011; Herrmann y Hutchinson, 2005) aunque no unánimes (Le Houérou, 1996; Olanrewaju y Koala, 2003). Otros factores biofísicos relacionados con la desertificación (ej. topografía, cubierta vegetal, etc.) pueden ser modificables a través de la acción humana pero con un coste social, ambiental y económico a veces inasumible. Por ello prestar atención a la combinación de factores naturales y antrópicos es imprescindible a la hora de afrontar la degradación de la tierra. Con todo, el factor humano es el más fácilmente transformable, debido a que hacerle frente a la componente antrópica de la degradación depende de la voluntad política, las medidas económicas y técnicas y la concienciación ciudadana (Breckle et al., 2001; Thomas, 1997).

Asumiendo la importancia del acceso al conocimiento y la sensibilización ciudadana para la lucha contra la desertificación, este trabajo se dedica, entre otras cuestiones, al estudio de los encuentros y desencuentros entre la ciencia y el conocimiento tradicional relativo a ella, entendiendo que la ciudadanía, y principalmente los generadores de conocimiento formal e informal y los gestores de la tierra, son parte fundamental de la solución de este fenómeno y no una víctima pasiva a la espera del rescate de las instituciones (Thomas & Middleton, 1994). Si bien el apoyo de las instituciones, sobre todo a escala local y regional es imprescindible para romper algunas de las barreras que impiden la implementación de medidas anti-desertificación.

Desertificación activa y desertificación heredada

La vigencia de los factores causantes de la desertificación es otro de los elementos que distorsionan la percepción construida en torno al fenómeno.

A la hora de tomar medidas en torno a la desertificación, es imprescindible identificar si nos enfrentamos a un proceso activo en la actualidad o al resultado de un proceso prolongado en el tiempo pero no vivo en el presente. Se establece así la diferencia entre los procesos de desertificación activos y los pasivos o heredados (Puigdefábregas y Mendizabal, 1998; Puigdefábregas, 2009).

La desertificación heredada o pasiva es el resultado de procesos de degradación importantes en el pasado pero que no están vigentes en la actualidad. Por lo cual la actuación sobre ellos se limita a la restauración, rehabilitación o recuperación en caso de haber dado lugar a estadios reversibles.

Por su parte las acciones de control de la desertificación activa deben centrarse en los causantes, al estar estos vigentes en la actualidad, y no sólo en la regeneración del sistema si es que los impactos son reversibles.

¿Un proceso irreversible?

La reversibilidad o irreversibilidad de la desertificación también condiciona la percepción en torno al problema y la voluntad para actuar frente a él.

A pesar de que ninguna de las definiciones institucionales y pocas definiciones técnicas hacen alusión a la reversibilidad de la desertificación (Glantz y Orlovsky, 1983), los procesos de desertificación pueden dar lugar a estadios finales reversibles o irreversibles.

Blum (2009) considera que son estadios irreversibles aquellos que no se pueden revertir en un período inferior a 100 años o equivalente a cuatro generaciones humanas. Algunos de los procesos que clasifica como agentes causantes de fenómenos irreversibles son: el sellado del suelo, la minería, la erosión hídrica y eólica, la contaminación por metales pesados o materiales radiactivos, la acidificación y salinización grave o la compactación en profundidad.

Por su parte Yassoglou y Kosmas (1999), definen como ejemplo de desertificación irreversible al estadio final de un proceso de erosión acelerado que ha reducido de forma permanente el espacio de enraizamiento y la capacidad de almacenamiento de agua del suelo, por debajo de los umbrales de tolerancia de las especies vegetales con valor económico y ambiental.

Otros autores, como Mainguet (1995), Le Houérou (1968) o Rozanov (1982) no hacen distinción sobre los agentes causantes sino que vinculan el fenómeno de la desertificación con procesos irreversibles (Cornet, 2002). Concretamente, Mainguet (1995), enuncia que son procesos de desertificación aquellos en los que la tierra se torna irreversiblemente estéril en términos económicamente aceptables o períodos temporales asumibles por el ser humano.

Esta conceptualización es demasiado excluyente y no alude a la mayor parte de los procesos de degradación, por ello entendemos que la reversibilidad del fenómeno es función del tipo, intensidad y duración del agente causante, del medio en el que actúe y del tiempo y coste económico, tecnológico y social que implique la recuperación o rehabilitación de la zona afectada.

La consideración tanto de la vigencia como de la reversibilidad de la desertificación, contribuyen a diluir la visión ineluctable e irreparable en cuanto al fenómeno y da cabida a la búsqueda de soluciones en el medio y largo plazo.

1.1.4. Abordando la desertificación desde perspectivas integradoras

Investigar sobre desertificación y en mayor medida diseñar políticas anti-desertificación requiere de un enfoque multiescalar, permeable a la influencia de distintas ciencias e igualmente sensible a las necesidades y prioridades de los actores involucrados en la cuestión. Para ello, es necesaria una actitud receptiva y versátil que fomente la colaboración entre los distintos agentes implicados. En definitiva, para hacer frente a la desertificación es necesario apostar por enfoques integradores.

En este sentido, diversas iniciativas han tratado de consolidar un marco conceptual que permita abordar la interrelación de los factores ambientales y humanos causantes de la desertificación, así como su heterogeneidad a escala temporal y espacial. Por su repercusión en el ámbito científico e institucional presentaremos algunas de ellas.

El marco Driving Forces-Pressures-States-Impacts-Responses

El marco Driving Forces-Pressures-States-Impacts-Responses (DPSIR) se centra en la identificación de los agentes causantes (*Driving forces*), las presiones ejercidas por ellos (*Pressures*), las modificaciones derivadas en el estado del sistema (*State*), los impactos generados (*Impacts*) y las respuestas (*Responses*) a la desertificación y otras cuestiones ambientales. Es un enfoque frecuentemente implementado por los gobiernos, las instituciones internacionales (ej. OCDE, Naciones Unidas, o EEA) y los científicos (Reynolds et al., 2011). Es práctico a la hora de sintetizar las relaciones entre factores socio-ambientales y resulta muy útil para ilustrar casos de estudio (ej. Haase y Nuissl, 2007; Ponce-Hernandez y Koohafkan, 2010) y estructurar y comunicar medidas políticas o resultados científicos referentes a estas relaciones.

A pesar de ser un marco ampliamente utilizado, presenta algunas carencias y ha sido criticado por la simplificación de la diversidad y complejidad de las interrelaciones socio-ambientales que suelen operar conjuntamente (Sommer et al., 2011). Tampoco refleja las relaciones causa-efecto (Reynolds et al., 2011) y plantea limitaciones a la hora de incorporar las dinámicas de los sistemas que intenta explicar (Svarstad et al., 2008).

Este marco conceptual reduce las dinámicas sistémicas a cadenas causales lineales y unidireccionales (Zucca et al., 2012), y obvia agentes no antrópicos claves en el cambio global. Igualmente en su implementación se suele delimitar la escala (Vogt et al., 2011; Zucca et al., 2007), cuando muchos fenómenos ambientales y particularmente la desertificación, son fenómenos multiescalares. El DPSIR también genera confusión al clasificar algunos factores en varias de las cinco categorías de análisis (Grainger, 2009b; Zucca et al., 2007) (ver ejemplo con el cambio climático y el turismo en la Figura 4). Pudiendo ser por tanto parte del problema pero también de la solución, lo que distorsiona la caracterización de los fenómenos que trata de abordar. Además, en el caso de la modelización de la desertificación, sintetizada en la Figura 4, se obvian cuestiones relevantes, como son los patrones de consumo vigentes que están fomentando la deforestación y la intensificación de la ganadería, para satisfacer así la demanda creciente de agrocombustibles (Altieri, 2009) o de proteínas animales en la dieta humana (Goodland, 1997).

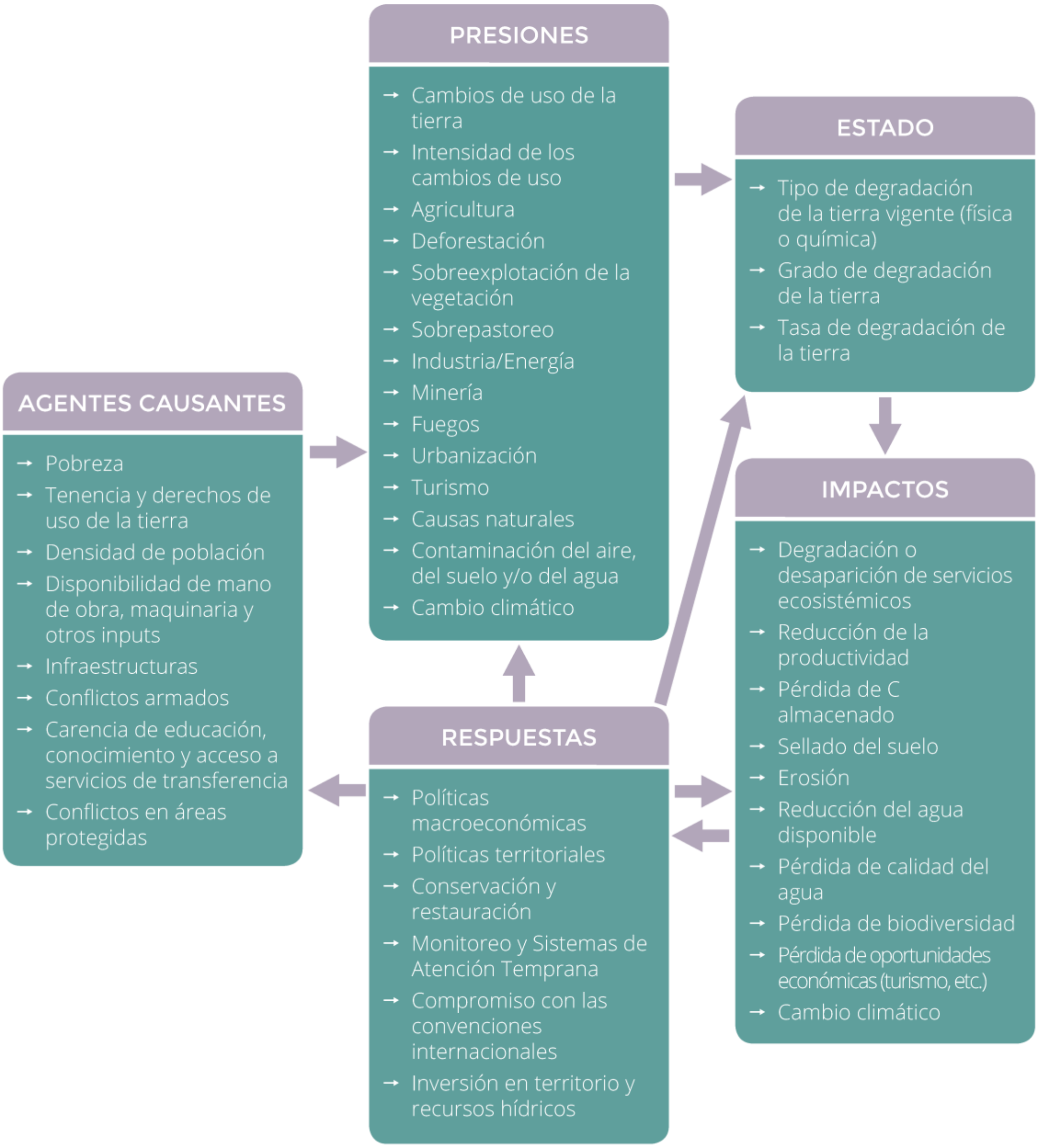


Figura 4: Caracterización de la desertificación mediante el marco DPSIR. Elaboración propia a partir de Smeets et al., (1999); EEA y UNEP (2000); Nachtergaele et al., (2013).

Por otra parte, Svarstad et al., (2008) señalan las carencias del DPSIR a la hora de fomentar la participación de los diferentes actores implicados y afectados por el diseño e implementación de políticas ambientales. Svarstad et al., (2008) destacan que la implementación tradicional del DPSIR, establece perspectivas de análisis y da lugar a intervenciones en las que se priorizan determinados enfoques y fuentes de conocimiento científico, lo que puede generar interpretaciones sesgadas al no incorporar adecuadamente el discurso y conocimiento de otros actores sociales implicados.

En el caso de la desertificación, la exclusión de actores sociales y específicamente de los generadores de conocimiento no formal y gestores de la tierra, es especialmente grave. Los usuarios son los conocedores de las prácticas tradicionales y el entorno socio-económico que determina el manejo del suelo y su consecuente conservación o degradación. Es por ello necesario revisar los mecanismos de implementación del DPSIR y evolucionar hacia marcos conceptuales más inclusivos.

La Teoría de los Síndromes

Algunos autores, como Hill et al., (2008), Scholes (2009) y Stellmes et al., (2013), se apoyan en la Teoría de los Síndromes, para analizar la desertificación. Esta teoría combina el conocimiento derivado de disciplinas científicas básicas, modelos interdisciplinares y del estudio de casos, para entender los mecanismos que rigen el cambio global. Apuesta por el valor de la información cualitativa, intuitiva y representativa y resta peso al rigor cuantitativo que suele dominar los estudios científicos clásicos. Todo ello, con el fin de caracterizar las interacciones entre procesos sociales y ambientales (esenciales en el concepto de síndrome) desde un punto de vista "arquetípico, dinámico, centrándose en la co-evolución de las interacciones biofísicos y humanas" (Petschel-Held et al., 1999).

En una primera aproximación susceptible a nuevas incorporaciones y revisiones, Petschel-Held et al., (1999) en colaboración con el *German Advisory Council on Global Change*, identificaron dieciséis síndromes que están conduciendo el cambio global (Tabla 3).

La Teoría de los Síndromes vincula los procesos de degradación con variables de estado socioeconómicas y naturales y es aplicable a diferentes escalas. Los síndromes pueden sucederse, excluirse (ej. *Favela* y *Expansión urbanística*), actuar individualmente, simultáneamente o retroalimentarse.

A diferencia del marco DPSIR que se fundamenta únicamente en fuentes científicas, la tipificación de los síndromes se basa en la opinión de expertos y en casos de estudio locales (Downing y Lüdeke, 2002). Por su potencial multiescalar, dinámico y por dar cabida a través de las modelizaciones y los casos de estudio al conocimiento tradicional no sistematizado formalmente, resulta una aproximación especialmente interesante para abordar la desertificación.

La Teoría de los Síndromes en una primera fase inductiva combina conocimiento formal e informal para lograr una aproximación preliminar al patrón de evolución de la interacción socio-ambiental que está analizando. Posteriormente a través de técnicas transdisciplinares intenta completar la información carente en relación a las condiciones y lugares en los que ocurre el síndrome en la actualidad y dónde se dan las condiciones óptimas para que surja a medio o largo plazo. Finalmente a través de técnicas de modelización tratan de minimizarse las incertidumbres existentes debido a la falta de información y se proyectan escenarios futuros de evolución del síndrome.

En el caso de la desertificación, el fenómeno es resultado de distintos síndromes que se manifiestan individualmente (ej. S*obreexplotación, Éxodo Rural, Dust bowl, Revolución Verde, Expansión Urbanística*, etc.) y se diferencian en función de la región, la disponibilidad de recursos, la economía y la presión poblacional. Por ello la desertificación se considera un síndrome multi-síndrome (Lambin et al., 2002), puesto que surge de la combinación y/o sucesión de varios síndromes del cambio global.

Tabla 3. Síndromes del cambio global, definidos por Petschel-Held et al. (1999) y el German Advisory Council on Global Change, clasificados según el uso antrópico de los bienes y servicios de los ecosistemas como: recursos para la producción, medios para el desarrollo socioeconómico o sumidero de los contaminantes derivados de los procesos anteriores. Fuente: Petschel-Held et al. (1999).

	DENOMINACION DEL SINDROME	DESCRIPCION GENERICA
USO DE RECURSOS	SAHEL	Sobrexplotación de tierras marginales
	SOBREEXPLOTACION	Sobrexplotación de ecosistemas
	EXODO RURAL	Degradación derivada del abandono de prácticas agrícolas tradicionales
	DUST BOWL	Uso agroindustrial no sostenible del suelo y el agua
	KATANGA	Degradación derivada del agotamiento de recursos no renovables
	TURISMO MASIVO	Urbanización y destrucción de espacios naturales para fines recreativos
	TIERRA QUEMADA	Degradación ambiental derivada de guerras y acciones militares
PROCESOS DE DESARROLLO	MAR ARAL	Deterioro de paisajes por el desarrollo de proyectos a gran escala
	REVOLUCION VERDE	Degradación debida a la transferencia e introducción de métodos agrarios inapropiados
	TIGRE ASIÁTICO	Vulneración de las condiciones ambientales y de salubridad para favorecer un crecimiento económico rápido
	FAVELAS	Degradación socio-ecológica por el crecimiento urbanístico incontrolado
	EXPANSIÓN URBANÍSTICA	Destrucción de paisajes derivada de la expansión planificada de infraestructuras urbanas
	DESASTRES	Desastres ambientales de origen humano con impactos a largo plazo
SUMIDERO	CHIMENEA	Degradación ambiental por la emisión a gran escala de sustancias no degradables
	VERTIDO DE RESIDUOS	Degradación ambiental por el vertido controlado e incontrolado de residuos
	TERRITORIO CONTAMINADO	Contaminación a escala local derivada de la actividad industrial

Cabe señalar que gran parte del conocimiento científico generado en torno a la desertificación, al menos en España y Argentina (los dos países donde hemos desarrollado un estudio exhaustivo de la bibliografía científica relativa a degradación del suelo), presta atención a la modelización de procesos biofísicos implicados en la desertificación, como pueden ser la erosión, la evolución de la cubierta vegetal, los regímenes de precipitación, etc. A pesar de que se echa en falta un enfoque más socio-ecológico de estos modelos, los resultados de la modelización de factores biofísicos es aplicable en la segunda y tercera fase de proyección de la evolución de las interacciones socio-ambientales relacionados con la degradación del suelo.

Por otra parte, tanto en España como en Argentina, el análisis de cuestiones relacionadas con el manejo tradicional o las medidas sociopolíticas no es tan patente. Por lo cual es fundamental la consideración de casos prácticos que pongan en valor el conocimiento tradicional y la diversificación de las fuentes de información consideradas en las primeras fases, para poder incorporar el conocimiento no formal y otros factores socioculturales y/o económicos a la caracterización de este síndrome multi-síndrome.

Los Paradigmas de Dahlem y Dryland Development

A diferencia del enfoque DPSIR, el Paradigma de Dahlem (Reynolds et al., 2003) y su versión revisada, el Paradigma *Dryland Development* (Reynolds et al., 2007) (ver Tabla 4), prestan especial atención a las interrelaciones entre los sistemas socio-económicos y biofísicos a distintas escalas espacio-temporales.

Estos paradigmas son coherentes con la Teoría de los Síndromes (Reynolds et al., 2007) y han sido específicamente ideados para el estudio de la desertificación. Proponen afirmaciones basadas en una aproximación jerárquica al fenómeno, que sean empíricamente evaluables, lo que permite una evolución dinámica de este marco conceptual (Reynolds et al., 2005).

Tabla 4. Principios del Paradigma de Dahlem y el Paradigma Dryland Development. Basado en Reynolds et al., (2007 y 2003).

PRINCIPIOS DEL PARADIGMA DE DAHLEM	PRINCIPIOS DEL PARADIGMA *DRYLAND DEVELOPMENT*
1. La desertificación incluye siempre condicionantes humanos y ambientales.	1. Los sistemas socio-ambientales son dinámicos y co-adaptativos, sus estructuras, funciones e interrelaciones varían a lo largo del tiempo.
2. Las variables "lentas"[9] son determinantes críticos de la dinámica del sistema.	2. Una pequeña selección de variables "lentas" son determinantes críticos de la dinámica del sistema.
3. Los umbrales son críticos y pueden cambiar en el tiempo.	3. Los umbrales de algunas variables "lentas" clave, definen los estados de los sistemas socio-ambientales, generalmente con diferentes procesos de control, además los umbrales pueden variar en el tiempo.
4. Los costes de intervención aumentan de manera no lineal con el aumento de la degradación.	4. Los sistemas socio-ambientales son jerárquicos y están interconectados a múltiples escalas.
5. La desertificación es una propiedad emergente a escala regional derivada de la degradación local.	5. Es fundamental mantener una base actualizada del conocimiento tradicional existente para la co-adaptación de los sistemas socio-ambientales.
6. Los sistemas socio-ambientales cambian en el tiempo.	
7. El desarrollo de un conocimiento ambiental a escala local apropiado debe ser acelerado.	
8. Los sistemas son jerárquicos.	
9. Una serie limitada de procesos y variables a cualquier escala hacen el problema gestionable.	

[9] Se entiende por variables "lentas" (ej. nutrientes edáficos) aquellas variables de estado que influyen en los flujos de bienes y servicios ecosistémicos y pueden usarse como parámetros para modelizar estos flujos (Carpenter y Turner, 2000). Las variables "lentas" se contraponen a las variables "rápidas" (ej. rendimiento de cosechas) que son muy sensibles a cambiar en el corto plazo y por ello no son adecuadas para la caracterización del estado de los sistemas socio-ambientales. Se considera que las variables "lentas" son determinantes en la evolución de los sistemas socio-ambientales (Holling et al., 2002), pero a la hora de identificar las variables "lentas" y "rápidas" de un sistema es importante atender también a la cuestión de escala

El Paradigma de Dahlem y el Paradigma *Dryland Development* asumen la no linealidad de los procesos, y dan importancia a la resiliencia y vulnerabilidad de los ecosistemas y las poblaciones, el conocimiento tradicional, la percepción humana, las estructuras sociales y los factores económicos para abordar la desertificación (Reynolds et al., 2003; Stafford Smith y Reynolds, 2002). Los principios en los que se basan no son desconocidos, pero su visión de conjunto supone en palabras de sus creadores, una "nueva aproximación a un viejo problema". Abordar estos principios implica (Reynolds et al., 2011, 2005; Stafford Smith y Reynolds, 2002):

- Integrar y analizar conjuntamente variables socioeconómicas y biofísicas.
- Asumir que los sistemas socio-ecológicos son dinámicos y están afectados por variables "lentas" que influyen en los flujos de bienes y servicios ecosistémicos y variables "rápidas" que tienen impactos más inmediatos en el bienestar humano.
- Asumir que los costes de la inacción aumentan significativamente una vez se superan determinados umbrales de degradación, por ello es importante potenciar la resiliencia de los sistemas y promover la acción urgente en el caso de que los umbrales críticos estén próximos.
- Definir con precisión la extensión espacio-temporal y los procesos derivados de la degradación a escala local.
- Analizar los tipos de síndromes de degradación de la tierra a distintas escalas.
- Entender y gestionar las circunstancias en las que los sistemas ambiental y humano se desacoplan.
- Fomentar la interrelación entre el conocimiento tradicional a escala local y la investigación científica, empleando diseños experimentales apropiados y sistemas de seguimiento e intercambio de información eficaces.
- Asumir que los sistemas socio-ecológicos son jerárquicos y gestionar el hecho de que los cambios de un nivel afectan a otros; crear instituciones flexibles pero ligadas a través de los niveles jerárquicos y asegurar que los procesos se gestionan con las instituciones adecuadas a cada escala.

Atendiendo a las limitaciones del modelo DPSIR por su simplificación de los procesos socio-ambientales o su fundamentación en fuentes prioritariamente técnicas, entendemos que bien la Teoría de los Síndromes o preferentemente por especificidad respecto a la desertificación, los Paradigmas de Dahlem y *Dryland Development* son los marcos conceptuales más apropiados para aproximarnos al tema.

Concretamente, en este trabajo se prestará atención a los principios 7 (Paradigma de Dahlem) y 5 (Paradigma *Dryland Development),* centrándonos en la identificación e integración del conocimiento tradicional y científico, así como en la necesidad de fortalecer la colaboración entre investigadores, gestores y usuarios de la tierra, ya que estos factores son parte de las componentes socioeconómicas de la desertificación menos abordadas.

1.2. LA DESERTIFICACIÓN EN ESPAÑA

1.2.1 Grandes cifras y agentes facilitadores

Tras revisar la dimensión más teórica de la desertificación, llega el momento de introducir el estado de la cuestión en el Estado Español.

España es el país de la Unión Europea más vulnerable a la desertificación (EEA y JRC EC, 2010). Atendiendo exclusivamente a criterios climáticos, más de dos terceras partes del Estado son susceptibles a este fenómeno. La mitad sur de la península (exceptuando las cadenas montañosas), la meseta norte, la cuenca del Ebro y la costa catalana se consideran zonas áridas, semiáridas y subhúmeda secas (Figura 5), ya que la proporción entre la precipitación anual y la evapotranspiración potencial está comprendida entre 0,05 y 0,65 (MMAMRMa, 2008).

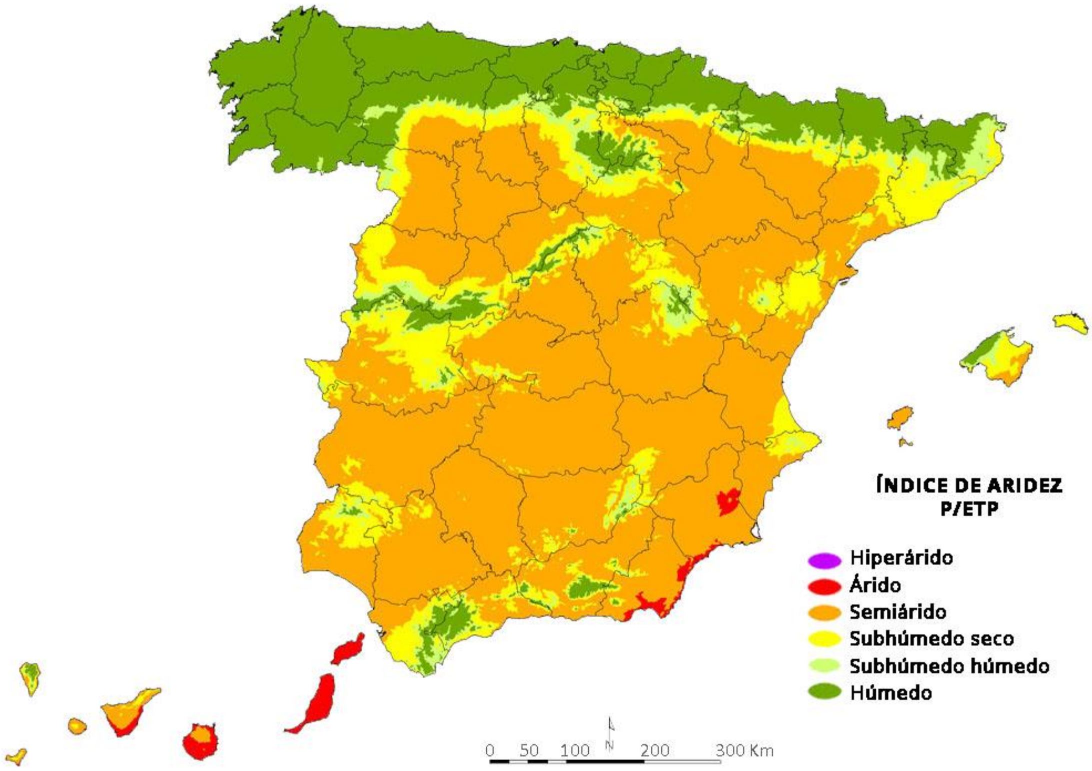


Figura 5: Mapa de aridez del Estado Español. Fuente: Programa de Acción Nacional Contra la Desertificación (MMAMRMa, 2008).

Las precipitaciones son escasas e irregulares, la media anual estatal ronda los 650 mm pero un 32% del territorio recibe tan sólo entre 300 y 500 mm de precipitación anual y en el sureste la media anual desciende hasta menos de 300 mm (MMAMRMa, 2008). La variabilidad de las precipitaciones, las sequías, así como la frecuencia de lluvias torrenciales, facilitan los procesos de desertificación (Sentis, 2006).

Si además de las condiciones climáticas se consideran otros factores socio-ecológicos, vigentes en España y en toda la región del Mediterráneo Norte (como señala el artículo 2 del anexo IV de la UNCCD relativo a esta región), la vulnerabilidad a la desertificación se hace más que evidente.

De hecho, del territorio español tan sólo quedan excluidas como zonas no vulnerables la Cornisa Cantábrica, Pirineos y las zonas más altas de los Sistemas Central, Ibérico y de la mitad sur de la península (Figura 6) (MMAMRMa, 2008).

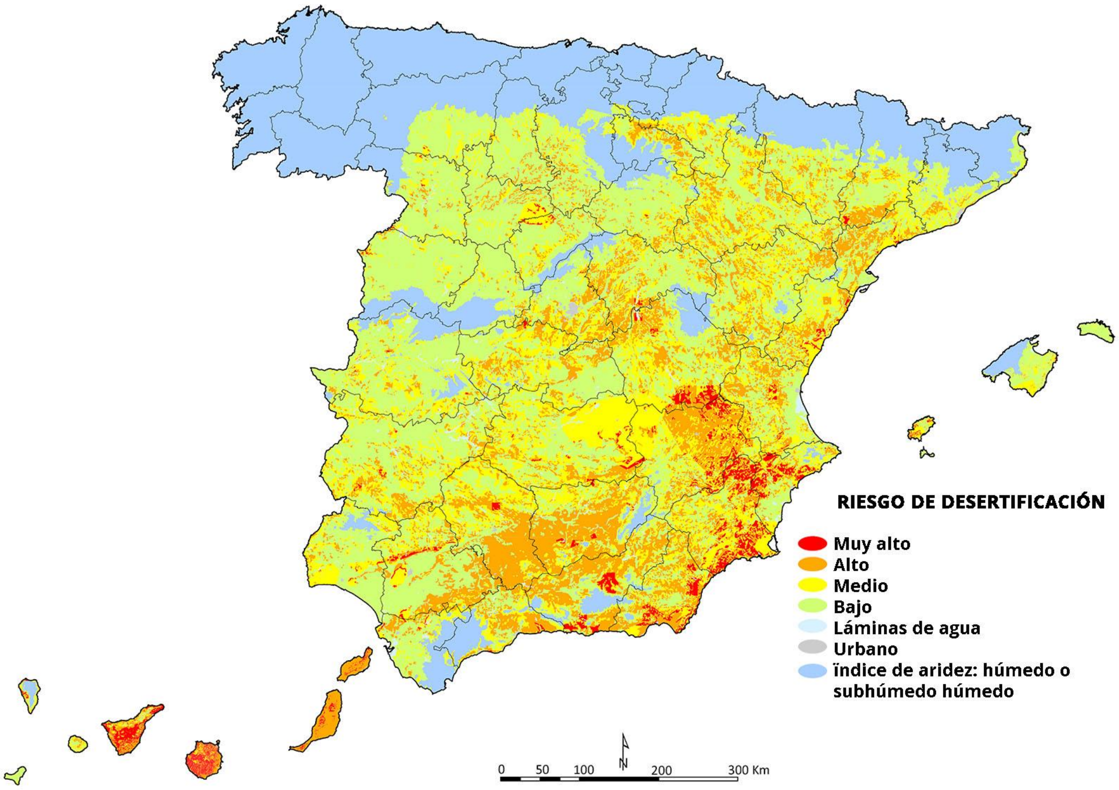


Figura 6: Mapa de riesgo de desertificación del Estado Español. Fuente: Programa de Acción Nacional Contra la Desertificación (MMAMRMa, 2008).

Entre los factores socio-ecológicos implicados en la degradación del suelo en España, merece la pena destacar:

La fragilidad de los suelos

La pedregosidad abundante, el escaso espesor del suelo, los perfiles esqueléticos, las texturas y estructuras erosionables, compactas o pesadas son rasgos edáficos característicos de muchos suelos españoles. Esto limita el desarrollo de actividades humanas y favorece procesos de degradación. En contrapartida, algunas cualidades favorables son: la frecuencia de texturas y estructuras equilibradas, la riqueza en nutrientes y algunos perfiles profundos (MMAMRMa, 2008).

En España las calidades del suelo se han visto afectadas por la larga tradición de explotación agrícola de la región Mediterránea (Puigdefábregas y Mendizabal, 1998), la climatología y la litología (MMAMRMa, 2008). Puesto que los dos últimos factores son difícilmente manipulables, parece que la lucha contra la desertificación desde el punto de vista edafológico pasa por la apuesta por prácticas sostenibles de gestión de la tierra y la reforma del marco político y económico para que estas resulten económica y socialmente viables.

El relieve es accidentado

La altitud media del territorio español alcanza los 680msnm, la pendiente media ronda el 17% y en torno al 32% de la superficie estatal tiene más de un 20% de pendiente (MAPA, 2003) (ver Figura 7). Estos indicadores ilustran la particularidad del relieve español.

A mediana y pequeña escala la pendiente, en combinación con la litología, la cubierta vegetal y el uso del territorio, juega un papel crucial en la pérdida y degradación de suelo por erosión, como así demuestran multitud de estudios desarrollados en España (Bracken y Kirkby, 2005; Cammeraat et al., 2005; Kosmas et al., 1997; MacDonald et al., 2000; Ruiz-Colmenero et al., 2013; Van Wesemael et al., 2003).

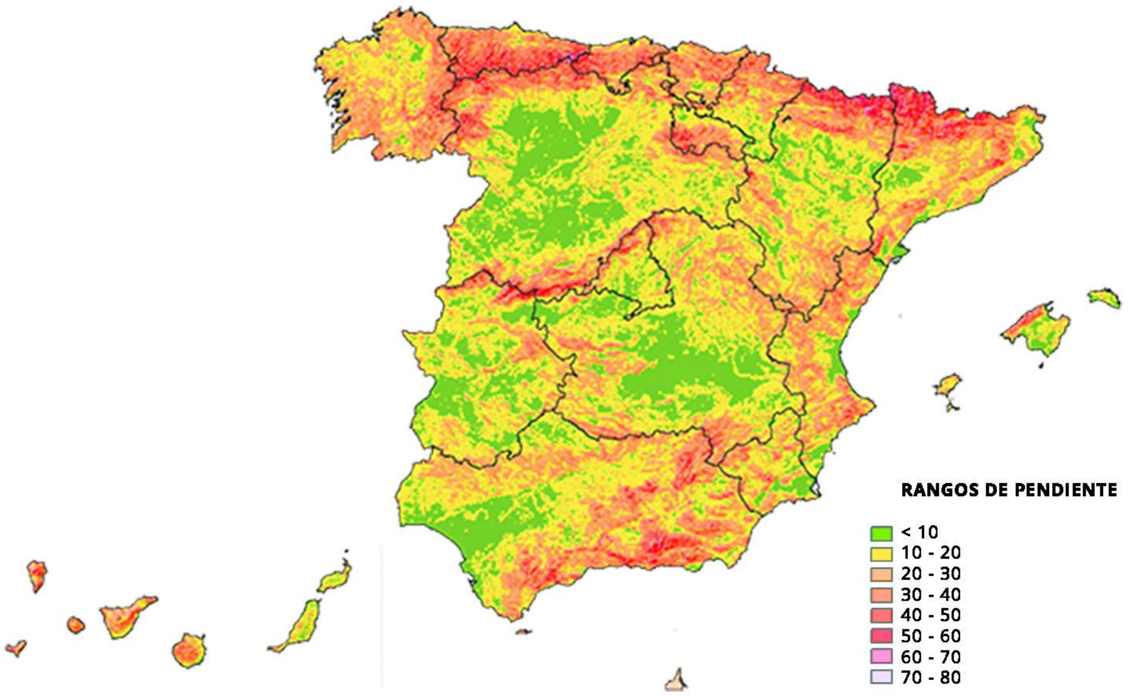


Figura 7: Mapa de pendientes del Estado Español. Fuente: Modificado de Sistema de Información Geográfica de Datos Agrarios del MAPA (SIGA) en (MAPA, 2003).

La topografía es uno de los factores físicos más comúnmente incorporados en los modelos de degradación de suelos (ej. De Alba, 2001; Gómez Gutiérrez et al., 2009; Kirkby et al., 2005; Reinhardt et al., 2007; Thornes y Alcantara-Ayala, 1998). Pero al igual que sucede con otros elementos biofísicos, los impactos de la topografía dependen en gran medida de las acciones humanas. El abandono de la agricultura (Lasanta et al., 2001) o de algunas técnicas tradicionales como el cultivo en terrazas (Faulkner, 1995; Lesschen et al., 2007) influyen notablemente en la degradación del suelo. Por otra parte la no explotación de zonas con pendiente, el cultivo y laboreo siguiendo las curvas de nivel o la incorporación de técnicas innovadoras como el uso de cubiertas vegetales son prácticas agrarias favorables para minimizar los efectos de la pendiente.

En este sentido, es necesario el apoyo institucional para frenar el abandono de la agricultura y de técnicas como el cultivo en terrazas y para fomentar las compensaciones económicas por la no explotación de zonas con pendiente pronunciada o para la adopción de técnicas innovadoras (Calatrava et al., 2010).

Por otra parte, para facilitar la implementación de técnicas como las cubiertas vegetales y otras técnicas innovadoras, el ámbito académico y los servicios de transferencia y extensión agraria juegan un papel clave. En los investigadores recae la responsabilidad de generar información actualizada, veraz e inteligible sobre los beneficios y limitaciones de estas técnicas. Por su parte, los servicios de transferencia y extensión agraria son los responsables de hacer llegar a los usuarios de la tierra estas informaciones y acompañarles para que se apropien de estas técnicas, puesto que en algunos casos el coste económico, la escasez de agua (Marques et al., 2010) o simplemente prejuicios asociados a lo que tradicionalmente se entiende por tierras de labor cuidadas, dificultan la implementación de estos métodos de conservación del suelo.

La erosión es un agente especialmente activo

La imagen de cárcavas y suelos erosionados es probablemente una de las que más se asocia al fenómeno de la desertificación.

Según señala el Programa de Acción Nacional contra la Desertificación, en el 46% del territorio se registran tasas anuales de pérdida de suelo superiores a las 12 toneladas por hectárea y en el 12% del territorio estas tasas llegan a superar las 50 toneladas. Comparando estas cifras con las tasas de formación de suelo, que varían entre 2 y 12 toneladas por año, se comprende la magnitud del fenómeno erosivo en España (MMAMRMa, 2008) (Figura 8).

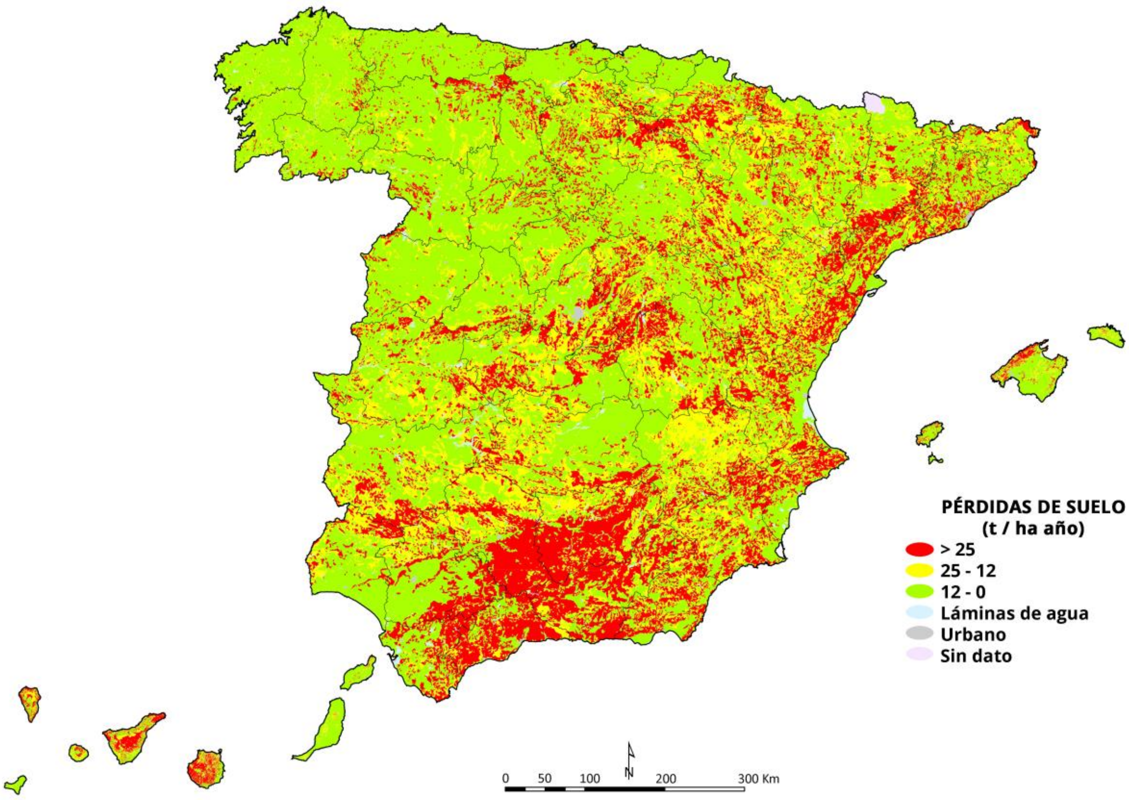


Figura 8: Mapa de estados erosivos del Estado Español. Fuente: Programa de Acción Nacional Contra la Desertificación (MMAMRMa, 2008).

Sin embargo, algunos autores consideran que estas estimaciones de pérdida de suelo son excesivas debido a cuestiones metodológicas y a que los procesos erosivos son más graves en los sistemas agrícolas que en los naturales (Martínez-Fernández y Esteve, 2005).

En cuanto a las debilidades metodológicas debe señalarse el uso extendido de la *Universal Soil Loss Equation* (USLE)[10] para los cálculos de pérdida de suelo a mediana o gran escala en entornos naturales. Esta ecuación fue diseñada para estimar la erosión en parcelas agrícolas de pequeña escala y como la literatura científica reconoce, su uso en espacios naturales y/o a gran escala, da lugar a sobreestimaciones de las tasas de erosión. Por otra parte, esta herramienta infravalora el papel de los matorrales en el control de los procesos erosivos, cuando este tipo de vegetación juega un papel relevante en el área mediterránea.

Atendiendo a estos matices, más allá de las estimaciones de pérdida de suelo, a la hora de afrontar la desertificación es importante diferenciar las causas económicas, humanas y políticas que motivan la erosión, puesto que es un agente especialmente activo en territorios intervenidos, como son los suelos agrarios, cuya explotación está estrechamente vinculada a las dinámicas comerciales, las directrices de la Política Agraria Comunitaria y la Ley del Suelo.

La cubierta vegetal está fuertemente antropizada

En condiciones idílicas de cero intervención, se estima que tan sólo un 5% del país no estaría ocupado por vegetación arbórea y arbustiva (MMAMRMa, 2008). Pero la intervención humana desde tiempos remotos ha hecho que a día de hoy los campos de cultivo, los pastos y el desarrollo urbanístico e industrial reduzcan las tierras forestales al 54.8% del territorio[11] (Carrión et al., 2010; MAGRAMA, 2014).

Sin embargo, entre 1990-2010 la superficie arbolada se ha incrementado a un ritmo anual del 2,19% (equivalente a 91.050 ha/año), siendo España el país de la Unión Europea con mayor incremento de la superficie forestal (Montero y Serrada, 2013). Por ello al abordar la desertificación, hay que considerar el papel que están jugando los procesos de reforestación y aforestación planificados, así como la matorralización espontánea. Aunque no exista consenso científico en cuanto a la matorralización como indicador de regeneración o degradación del territorio, pero sí del suelo, al menos en el caso de tierras agrícolas abandonadas sin cubierta permanente (Eldridge et al., 2011; Maestre et al., 2009; Parizek et al., 2002).

[10] La ecuación USLE fue formulada por el Departamento de Agricultura de Estados Unidos (USDA, siglas en inglés) en la década de los sesenta. La ecuación se fundamenta en una extensa experiencia del estudio de la erosión en EEUU y permite estimar rápidamente la media anual de pérdida de suelo a largo plazo. La ecuación es: A=RKLSCP (Wischmeier y Smith, 1978).

[11] Se consideran tierras forestales las zonas arboladas, de matorral o matorralizadas, así como los eriales en estadios sucesionales. Bajo este amplio paraguas se agrupan en España 27,5 millones de hectáreas, de las cuales tan sólo 18,6 millones de hectáreas son cubierta forestal arbolada (MMAMRMb, 2008).

La incidencia de los incendios forestales

Los incendios forestales son un agente importante de degradación del suelo por pérdida duradera de la cubierta vegetal y su consecuente exposición a la erosión hídrica (Campo et al., 2006; Mallinis et al., 2009).

Los períodos de sequía influyen en la incidencia de los incendios. Pero múltiples factores socioculturales son agentes potenciales de riesgo de incendios. Por una parte la expansión del urbanismo hasta límites colindantes con áreas forestales (Badia et al., 2002) incide en la ocurrencia de incendios accidentales y provocados. Pero un factor crítico en la declaración de incendios es el incremento de la biomasa (ej. matorral), derivada del abandono de las tierras agrícolas (Bodí et al., 2012; Shakesby, 2011) y de la pérdida de sistemas tradicionales de gestión forestal, así como del cambio de la base energética de la leña a otros combustibles.

Tanto el abandono de tierras agrícolas, como la gestión forestal y la urbanización requieren de iniciativas políticas y legislativas para la mitigación de sus efectos negativos.

La crisis prolongada en la agricultura

Las políticas agrarias, la modificación del marco legislativo en torno a suelo rústico y urbanizable y otros agentes socioeconómicos (ej. burbuja del sector inmobiliario) han fomentado las dinámicas de cambio de usos del suelo que han transformado el sector agrario. Esta transformación ha dado lugar al abandono de tierras y el deterioro del suelo y de las estructuras de conservación del agua en algunas zonas (García-Ruiz, 2010) y a la intensificación y sobreexplotación de recursos en otras (Nainggolan et al., 2012).

En este sentido, la reestructuración y apoyo al sector agrario, es clave no sólo en términos económicos y sociales, sino también ambientales puesto que una de las principales barreras para la implementación de técnicas de manejo sostenible del suelo parece ser la falta de recursos económicos disponibles para asumir los costes de esta transformación (Odendo et al., 2010; Schwilch et al., 2014).

La explotación insostenible de los recursos hídricos subterráneos y superficiales

La intensificación del turismo, el urbanismo, la industria y la agricultura ha dado lugar a la sobreexplotación, contaminación y salinización de los acuíferos y otros recursos hídricos, como ha sido ampliamente estudiado en España (Auernheimer et al., 2001; Barros et al., 2012; Maestre Gil, 2001).

El consumo de agua per cápita se estima en 71m^3 por año, siendo este uno de los más altos de la UE, tan sólo por detrás de Chipre y Grecia (EUROSTAT, 2014). Las características climáticas de España inciden notablemente en el consumo per cápita de agua distribuida por aducción, lo que sumado a la presión ejercida por el regadío explica la situación de explotación de los recursos hídricos.

La agricultura, representa en torno al 75% del consumo de agua en España (INE 2008). Según el INE (2014), en 2012 se destinaron a la agricultura 15.833 hm^3 de agua, de los cuales más de

6.000hm^3 se dedicaron al riego por gravedad. Resulta paradójico que en un país donde la disponibilidad de agua es limitada, exista aún un arraigo tan fuerte de esta técnica, ya que más de un 27% de la superficie de regadío se irriga por gravedad. Este dato evidencia la necesidad de dar continuidad y fortalecer las medidas destinadas a la modernización y mejora de la eficiencia del riego en agricultura.

Concentración de la actividad económica en las zonas costeras y en los principales núcleos urbanos

Este fenómeno ha originado un crecimiento urbano e industrial (Pascual Aguilar et al., 2006), en muchos casos incontrolado, y una intensa presión sobre los recursos naturales en las zonas costeras, los archipiélagos balear y canario, las cuencas fluviales del Ebro y el Guadalquivir y la capital del país. En contraposición, en las zonas interiores, se produce un progresivo despoblamiento y abandono de las actividades tradicionales (Rey Benayas et al., 2007; Serra et al., 2008).

España presenta la paradoja de situarse en ambos extremos de la polaridad entre abandono y expansión urbanística incontrolada, a nivel europeo, habiendo sido utilizada para ilustrar este último fenómeno por la EEA (EEA, 2006) (Figura 9).

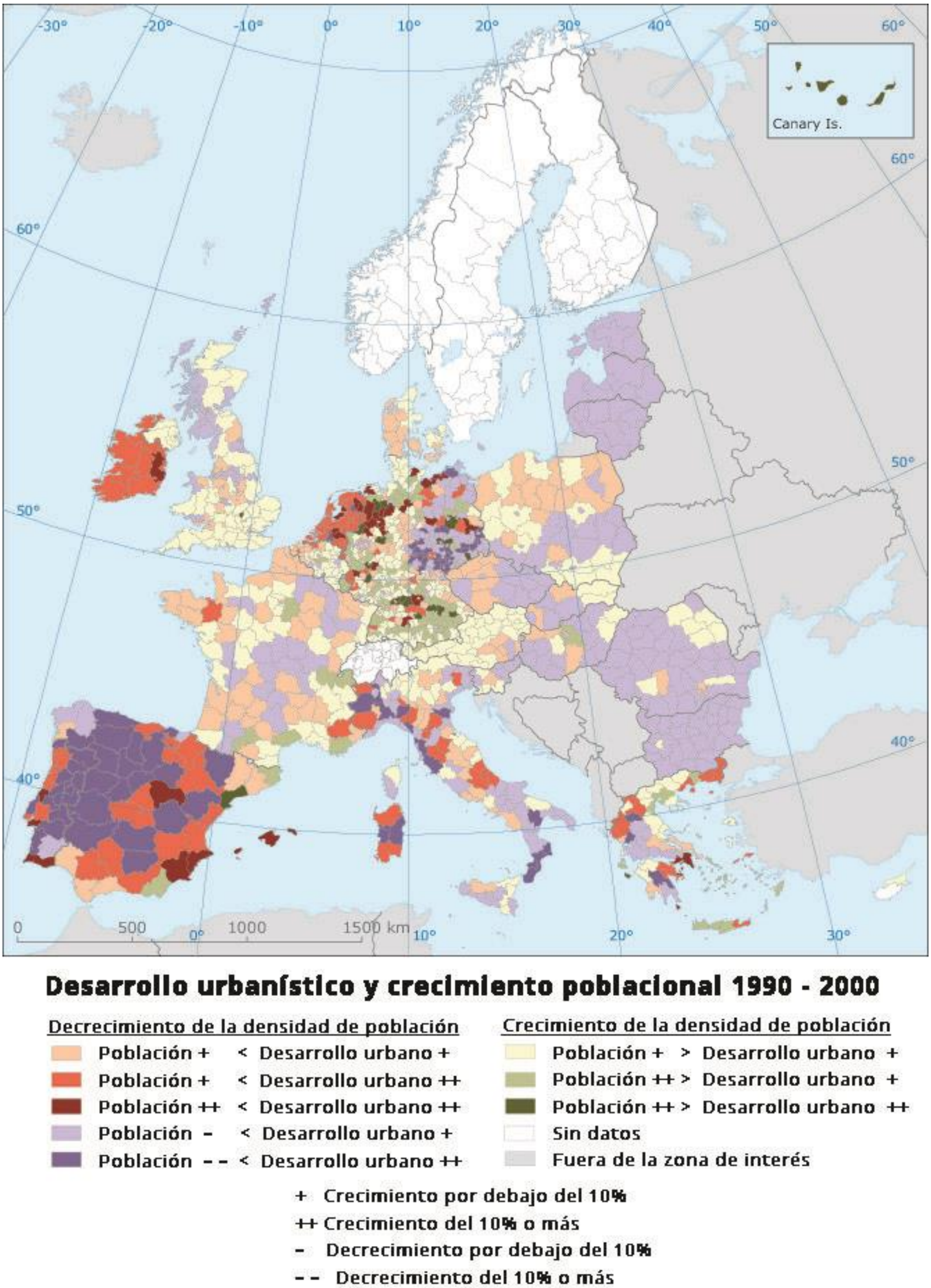


Figura 9: Mapa de desarrollo urbanístico y crecimiento poblacional en la UE entre el año 1990 y 2000. Fuente: (EEA, 2006).

La crisis de la agricultura y la concentración urbana, son determinantes para la elección de nuestra zona de trabajo de campo. El Programa de Acción Nacional Contra la Desertificación (PAND) vincula la mayor parte de los escenarios de la desertificación en España a las zonas sur, este y sureste y en menor medida a la región central (MMAMRMa, 2008). Igualmente, gran parte de la ciencia desarrollada en torno a la desertificación en España, también se focaliza en estas zonas. La región menos explorada quizás es el área central, lo que junto a sus particularidades socioeconómicas, confiere especial relevancia a nuestro estudio, desarrollado en la zona centro, concretamente en la Comunidad de Madrid (CM). En la CM los condicionantes biofísicos de la desertificación pueden no ser tan alarmantes como en otras zonas, pero la componente socio-ambiental es particularmente llamativa (Figura 10). Se trata de una región sometida a una fuerte presión urbana en la que el sector agrícola, si bien ocupa una superficie importante, económica e incluso socialmente es considerado como residual. Esta marginalización del sector ha inducido dinámicas de abandono de la agricultura, dificulta la gestión sostenible del suelo y durante los años de pujanza económica fomentó la transformación de la tierra a estadios no reversibles derivados del *soil sealing* o sellado permanente a consecuencia de la urbanización.

FACTORES PUSH	FACTORES PULL
1. Reducción de la fertilidad del suelo	1. Prioridad de abastecimiento de agua para zonas urbanas y turísticas
2. Escasez de agua para usos agrícolas	2. Rentabilidad del sector inmobiliario y falta de alternativas de inversión
3. Pérdida de rentabilidad de la agricultura	3. Rápido crecimiento de los precios del suelo urbanizable
4. Depreciación de las tierras agrarias	4. Incentivos fiscales para la adquisición de propiedades inmobiliarias
5. Promoción del abandono de tierras menos rentables por causa de la PAC	5. Políticas de desarrollo urbanístico agresivas
6. Debilidad de las políticas de uso del territorio en relación a cuestiones ambientales	6. Salarios atractivos en el sector de la construcción e inmobiliario
7. Éxodo rural / migraciones rural-urbanas	7. Crecimiento de las áreas urbanas y turísticas

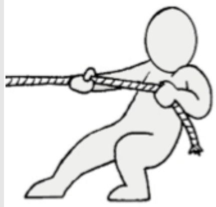


Figura 10: Dinámica *push-pull* de abandono de tierras agrarias y su periurbanización, clásica de numerosas zonas sometidas a procesos de desertificación y especialmente relevante para el SE de la CM. Fuente: Barbero et al., (2012).

Retomando la importancia de la combinación de factores biofísicos y socio-ambientales a escala estatal, se evidencia, que en el marco de la Unión Europea, el Estado Español es donde más urgente se hace la concienciación ciudadana, la formación de los gestores y usuarios de la tierra, así como el fortalecimiento de la voluntad política para combatir la desertificación (Oñate y Peco, 2005). Atendiendo a estas necesidades y al compromiso adquirido con la UNCCD, en 2008 se publicó el PAND, que constituye el principal instrumento administrativo en la materia a escala nacional.

1.2.2 El Programa de Acción Nacional de Lucha Contra la Desertificación

El Estado Español firmó el 14 de octubre de 1994 y ratificó en enero de 1996 la Convención de la Naciones Unidas de Lucha Contra la Desertificación. El 11 de febrero de 1997, el texto de la UNCCD fue publicado en el BOE nº 36, adquiriendo así rango de Tratado Internacional de obligado cumplimiento para nuestro país.

Como parte de su compromiso con la UNCCD, el Gobierno Español a través del Ministerio de Medio Ambiente, inició en 1996 el proceso de elaboración y publicó en 2008 el Programa de Acción Nacional de Lucha Contra la Desertificación (MMAMRMa, 2008).

El PAND establece dos objetivos principales:

1. Contribuir al logro del desarrollo sostenible de las zonas áridas, semiáridas y subhúmedas secas del territorio nacional y, en particular, la prevención o la reducción de la degradación de las tierras, la rehabilitación de tierras parcialmente degradadas y la recuperación de tierras desertificadas.
2. Determinar cuáles son los factores que contribuyen a la desertificación y las medidas prácticas necesarias para luchar contra ella y mitigar los efectos de la sequía.

Para alcanzar estos objetivos, el PAND se guía por varios principios. Se propone definir estrategias a largo plazo e integrarse en la política nacional de desarrollo sostenible. Pretende ser flexible para facilitar la introducción de modificaciones de acuerdo a las circunstancias cambiantes en el futuro y atender a la sensibilidad territorial para adaptarse a las distintas condiciones socioeconómicas, biológicas y geofísicas. Presta atención especial a la aplicación de medidas preventivas para las tierras aún no degradadas, pero que están sometidas a riesgos potenciales de desertificación. Promociona la coordinación institucional y de diseño y desarrollo de políticas para la implementación de las distintas acciones sectoriales. Promueve la participación de todos los sectores de la sociedad implicados. Igualmente el PAND trata de promover sinergias con otros Convenios y acuerdos ambientales internacionales (MMAMRMa, 2008).

La formulación de los principios que rigen el PAND parece coherente con el carácter dinámico, multiescalar y multiactor de la desertificación, así como con el coste de la inacción a medio y largo plazo. En cambio estas sensibilidades teóricas se desvanecen cuando se indaga en el alcance y existencia de medidas tangibles de lucha contra la desertificación.

El tipo de medidas que propone el PAND alude a:

- Las esferas legislativa, institucional y administrativa.
- Las modalidades de uso de la tierra, la ordenación de los recursos hídricos, la conservación del suelo, la silvicultura, las actividades agrícolas y la ordenación de pastizales y praderas.
- La ordenación y conservación de la fauna y flora silvestres y otras manifestaciones de la diversidad biológica.
- La protección contra los incendios forestales.
- La promoción de medios alternativos de subsistencia.
- La investigación, la capacitación y la sensibilización del público.

Según señala el propio documento, el PAND "establece principios y diseña acciones y su programación en el tiempo, respondiendo a las preguntas cómo, cuándo y dónde actuar respecto del problema de la desertificación" (MMAMRMa, 2008). Sin embargo, olvida cuestiones esenciales a la hora de ejecutar políticas eficaces, como son el quién debe implementar las acciones diseñadas y con qué fondos económicos se cuenta para costear los recursos técnicos y profesionales necesarios para ello.

El PAND pretende jugar un papel catalizador de las medidas relacionadas con el control de la desertificación, que están ya incluidas en las políticas y planificaciones sectoriales, o si fuese necesario proponer su inclusión.

Con este espíritu, el PAND compila una selección variopinta de acciones relacionadas con distintos sectores (ej. sector agrario, forestal) y actores (ej. organizaciones sociales, sector privado, etc.) que aunque no focalicen sus iniciativas específicamente en la desertificación si tienen relación directa o indirecta con ella.

Como propuestas de acción concretas hace hincapié en cuatro líneas de actuación:

1. La determinación de áreas con riesgo de desertificación.
2. Las medidas de lucha contra la desertificación, relacionadas con: el uso de la tierra, la ordenación de los recursos hídricos, la conservación del suelo, la silvicultura, las actividades agrícolas, la ordenación de pastizales y praderas, la protección contra incendios forestales y la investigación, capacitación y sensibilización del público en torno al fenómeno.
3. La coordinación de políticas.
4. La identificación y desarrollo de líneas de acción específicas de lucha contra la desertificación.

Si bien el PAND hace una compilación detallada de las medidas y los instrumentos ya existentes en relación a cada una de estas líneas de acción, varias son las debilidades que dificultan su aplicación real.

Por una parte el posible sobredimensionamiento de la extensión territorial afectada por la desertificación en España así como la propagación de mensajes catastrofistas[12] en torno al tema, genera incertidumbre y alimenta la idea de que es un problema irresoluble, desalentando la implicación política y ciudadana.

El programa presta atención al sector agrario, forestal o de gestión de recursos hídricos, pero menoscaba la importancia del sector urbanístico en la degradación del suelo. El PAND concede una atención insignificante al urbanismo cuando esta es una actividad que compite con las anteriores, era uno de los principales motores de la economía, estaba en pleno vigor en el momento de la aprobación del PAND y además es causante de fenómenos de degradación irreversible debido al impacto del sellado del suelo derivado de la expansión urbanística.

El PAND es un instrumento de marcado carácter tecnocrático. A pesar de tratar de integrar a diferentes agentes sociales a través de procesos de consulta a lo largo del período de elaboración, el PAND no ha sido capaz de asumir el potencial de los gestores de la tierra y portadores de conocimiento agrario tradicional, como agentes activos en la lucha contra la desertificación.

Este hecho es aún más evidente, al revisar el tipo de propuestas que se compilan en el Inventario de Tecnologías de Lucha Contra la Desertificación (MAGRAMA, 2009), vinculado al PAND. Las iniciativas recogidas en el inventario aluden a distintas áreas en las que los

[12] Titulares como “La desertización amenaza a más del 30 % de España” (El Mundo, 2006) o “El desierto avanza sobre España” (De Benito, 2008) han sido difundidos por medios de comunicación de impacto nacional coincidiendo con fechas puntuales como la aprobación del PAND o el día mundial de la lucha contra la desertificación.

agricultores y ganaderos disponen de una dilatada experiencia, en cambio sólo se hace mención explícita a técnicas tradicionales en el apartado referente a aprovechamiento del agua. El resto de tecnologías compiladas se caracterizan por derivar de la experiencia científica y requerir una inversión económica o un conocimiento específico y medios técnicos poco frecuentes en el sector agrario.

Por último, una de las principales debilidades del PAND es la carencia de una estructura y un presupuesto concreto para su aplicación.

En la formulación del PAND se diluye esta flaqueza aludiendo a que este programa es una herramienta integradora de un conjunto de medidas derivadas de políticas, planes y programas sectoriales ya existentes. Y por ello son los propios sectores implicados en el desarrollo de las medidas incluidas en el PAND (ej. sector agrario y forestal, sector de gestión de los recursos hídricos, etc.) quienes deben orientar sus presupuestos hacia la consecución de los objetivos del PAND.

El propio documento menciona que “el marco institucional, legislativo y el desarrollo práctico de cada sector implicado constituye una realidad tangible, previa a la ratificación de la Convención de Lucha Contra la Desertificación, que además responde a sus propias políticas, desde luego no de forma aislada o autónoma, pero primordialmente condicionada por la armonización de sus propios conflictos de intereses. Estos intereses superan en relevancia económica directa y/o convencional y percepción social asociada, a los de la lucha contra la desertificación” (MMAMRMa, 2008).

A pesar de que esta asunción convertiría inmediatamente al PAND en una estrategia ineficaz, amparándose en la visión a largo plazo para la aplicación de la Convención y la consecución del desarrollo sostenible (marco en el cual se elabora el programa), este documento reafirma su valor como catalizador. El PAND pretende ser “un instrumento que oriente y proporcione las claves para que las políticas evolucionen hacia la sostenibilidad de las zonas áridas y semiáridas”, pero “dado que cualquier recurso, sector o actividad potencialmente relacionada o concernida por los procesos de desertificación dispone en España, (……), de un tratamiento institucional y legislativo específico, la lucha contra el fenómeno no estará caracterizada por la creación de políticas, sino por la adaptación, armonización y coordinación de las previamente existentes” (MMAMRMa, 2008).

La adaptación, armonización y coordinación de políticas requiere la modificación de determinadas líneas de inversión y la creación de algunas nuevas. En cambio, no se dispone para ello de partidas adicionales a las ya previstas en otros planes y programas. El ejercicio de reestructuración presupuestaria debe ser llevado a cabo por la Administración General del Estado y por las Administraciones autonómicas y locales. No obstante, actualmente no se dispone de ningún mecanismo verificable para cuantificar la inversión específica y real dedicada a frenar la degradación de la tierra en España e identificar quiénes son los financiadores y gestores directos de los recursos públicos dedicados a la lucha contra la desertificación.

Como conclusión, el PAND cumple el compromiso formal de elaborar un Programa Nacional para luchar contra la Desertificación previsto en la UNCCD, sin embargo, la inexistencia de un presupuesto específico, así como la marginalización de sectores y actores clave en la lucha contra la desertificación, lo convierten en un documento teórico. Es una referencia útil para justificar los compromisos del Estado Español respecto a la UNCCD, pero ineficaz como estrategia y guía de sistematización y coordinación de actividades aplicadas en la lucha contra la desertificación local, autonómica y estatalmente.

1.3. DEL PAPEL A LA ACCIÓN: UNA INVESTIGACIÓN CON LAS MANOS EN LA TIERRA

Según la FAO aproximadamente el 38% del territorio global y el 55% del territorio español se consideran tierras agrarias (FAO Statistics Division, 2015) y de ellas el 52% están sometidas a un riesgo de degradación entre moderado y severo. Por otra parte la UNCCD estima que cada año a consecuencia de la desertificación y la sequía se pierden en torno a 12 millones de hectáreas cultivables, lo que implica la alarmante tasa de pérdida de 23 ha/min (UNCCD, 2013).

Revertir y controlar la degradación del suelo supone apostar decididamente por el Manejo Sostenible de la Tierra (SLM, siglas en inglés). En la Conferencia de la Tierra (1992), se definió el SLM como "el uso de los recursos del territorio, incluyendo el suelo, el agua, los animales y plantas, para la producción de bienes que respondan a las necesidades cambiantes del ser humano, a la vez que se asegura el potencial de producción de estos recursos a largo plazo y la continuidad de sus funciones ambientales".

El SLM es una respuesta a diversos retos globales como el cambio climático, la pérdida de biodiversidad o la seguridad alimentaria. Pero fundamentalmente, la implementación de prácticas y tecnologías de SLM son una oportunidad para frenar la degradación de la tierra (Schwilch et al., 2012a) y contribuir a la meta 2.4 de los recientemente aprobados Objetivos de Desarrollo Sostenible para 2030 de Naciones Unidas[13] (UN, 2015).

El SLM es una estrategia frecuentemente mencionada en la agenda política internacional y un concepto arraigado en el ámbito científico. En cambio son pocos los usuarios de la tierra que se identifican con este término a pesar de conocer o estar desarrollando prácticas tradicionales sostenibles o innovaciones propiamente alineadas con él (Schwilch et al., 2012b).

En cuanto al SLM y otras dimensiones del suelo, el ámbito científico es una fuente de conocimiento sistematizado, contrastable, actualizado y generalmente transferible (*know-why*) (Lundvall y Johnson, 1994). El *know-why* científico es capaz de identificar e interrelacionar las dinámicas que están dando lugar al cambio global e inciden directamente en la degradación del suelo a distintas escalas.

Por su parte, los usuarios de la tierra atesoran conocimientos tradicionales (*know-how*) coherentes con las necesidades y las prioridades locales, así como alineados con los valores culturales, religiosos y sociales de la zona (Fagerholm et al., 2012). Por la especificidad del conocimiento tradicional que rige parte de sus decisiones así como por ser los responsables directos de la gestión de la tierra, los usuarios son consecuentemente actores clave en la lucha contra la degradación del suelo.

El conocimiento generado por los usuarios de la tierra a través de la experiencia práctica y la transferencia de saberes tradicionales generación tras generación, es un recurso invaluable. De hecho, algunos autores consideran que el conocimiento es el "cuarto factor de producción" debido al amplio rango de informaciones, habilidades y aptitudes que los usuarios de la tierra

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[13] El Objetivo de Desarrollo Sostenible 2 pretende poner fin al hambre, conseguir la seguridad alimentaria y una mejor nutrición, y promover la agricultura sostenible. Dentro de este objetivo, la meta 2.4 hace referencia a: Asegurar la sostenibilidad de los sistemas de producción de alimentos e implementar prácticas agrarias resilientes que incrementen la productividad y producción, contribuyan al mantenimiento de los ecosistemas, fortalezcan la capacidad de adaptación al cambio climático, los fenómenos meteorológicos extremos, las sequías, las inundaciones y otros desastres, y que progresivamente mejoren la calidad del suelo y la tierra.

tienen que gestionar para poder sacar adelante sus cosechas y productos ganaderos (Ingram, 2008; Winter, 1997).

Según se ha comentado, la UNCCD reconoce explícitamente este hecho y recoge la necesidad de incorporar dicho conocimiento a través de una participación apropiada de los agricultores y otros agentes sociales gestores del suelo (UNCCD, 2005). Desde esta perspectiva la UNCCD sería la más avanzada de las “Convenciones de Río”.

Pese a ello, los usuarios de la tierra han sido tradicionalmente entendidos por las instituciones y los científicos como agentes pasivos, meros receptores de información (Winter, 1997). Por esta razón, avanzar hacia modelos de gestión del conocimiento integrados que reconozcan el valor del saber hacer tradicional y la importancia de la interacción y retroalimentación entre conocimiento científico (*know-why*) y tradicional (*know-how*) es un requisito importante para fortalecer el conocimiento relativo a la degradación del suelo y sus métodos de mitigación (Schwilch et al., 2014).

1.3.1. Actores y beneficiarios de la gestión del suelo

La implementación del SLM involucra a diversos actores, con distintos grados de responsabilidad. Entre ellos destacan la administración pública, la sociedad civil, el sector privado, los investigadores y los usuarios de la tierra (De Pina Tavares et al., 2014; Schwilch et al., 2012a).

La sociedad civil y el sector privado disfrutan de los bienes y servicios provistos por el suelo y se ven afectados por los impactos de su deterioro.

El sector privado debido a su carácter lucrativo juega un papel determinante. La maximización de los beneficios económicos suele inducir la sobreexplotación y degradación del suelo puesto que las dinámicas de mercado actuales no reflejan el valor real de los bienes y servicios ecosistémicos y el coste de su degeneración (Tilman et al., 2002). Sin embargo, algunas empresas innovadoras han sido capaces de identificar y dar respuesta a la creciente demanda, principalmente en Europa y Estados Unidos (Lohr, 2001), de productos agroalimentarios y cosméticos responsables con el entorno y la calidad de vida de los agentes implicados en su producción. Este segmento del sector privado ha ocupado un nicho de mercado, en el que sus productos suelen recibir un precio superior a los convencionales. Pero, precisamente ese incremento comparativo del precio de los productos responsables, así como otros factores inherentes al perfil del consumidor consciente (ej. sensibilidad ambiental y preocupación por la salud, nivel adquisitivo y educativo, etc.) son barreras importantes para la expansión de esta línea de negocio (Gil et al., 2000).

La sociedad civil es un agente clave como actor participativo en el diseño de políticas de gestión sostenible del suelo (Schwilch et al., 2009). La concienciación social respecto a la conservación de los recursos naturales, es fundamental a la hora de ejercer presión y seguimiento de las acciones que las administraciones han de llevar a cabo para garantizar el derecho de la ciudadanía a disfrutar de un entorno sano. Pero además de su papel como actor político activo, la sociedad civil a través de su poder como consumidor, puede contribuir a la trasformación del sector agroalimentario hacia modelos más coherentes con los límites socio-ecológicos del planeta (Paül y McKenzie, 2013).

Por su parte, la administración pública es oficialmente la garante de la conservación y mejora de la gestión ambiental. Igualmente, la administración es responsable del desarrollo e implementación de políticas relativas a los usos del territorio y la mitigación de la desertificación (Juntti y Wilson, 2005; Vogt et al., 2011) y al sector agrario, turístico y urbanístico (Carrero et al., 2009; Pascual Aguilar et al., 2006; Salazar-Ordoñez y Sayadi, 2011), que inducen impactos notables sobre el suelo. Concretamente, centrándonos en la gestión del conocimiento, la administración pública, en el caso de nuestro país a escala de las Comunidades Autónomas, ejerce las competencias en materia de transferencia agraria y es por ello un eslabón clave en la comunicación entre investigadores y gestores de la tierra.

Siendo conscientes de la importancia de cada uno de los actores mencionados en la implementación del SLM, en este estudio, por su relevancia como generadores, gestores y trasmisores de conocimiento en torno al suelo, se focaliza la atención en los investigadores (generadores de *know-why*) y en los usuarios de la tierra (poseedores del *know-how*). En el caso de los usuarios, esta atención atiende además al impacto que sus percepciones y decisiones tienen sobre el presente y futuro de los suelos, ya que los usuarios son los gestores directos de la tierra.

1.3.2. El *know-why* y el *know-how*: encuentros y desencuentros

El conocimiento tradicional, si bien no siempre coincide con prácticas de manejo sostenible, es un conocimiento más holístico que el científico (Desbiez et al., 2004). Las prioridades de los usuarios de la tierra suelen responder a criterios de productividad y calidad del producto (Mairura et al., 2008; Subedi et al., 2009). Y para responder a estas prioridades, los usuarios manejan *know-how* no sólo relativo al suelo, sino también a la climatología, la disponibilidad de agua, las semillas, las rotaciones, la distribución del trabajo, los valores culturales de la zona, etc.

Este conocimiento tradicional integra criterios económicos, biofísicos y socio-culturales en la gestión del suelo (componente fundamental del *land approach*) y es resultado de la experiencia colectiva, a través de la observación, la práctica y la prueba y error de sucesivas generaciones (Ingram, 2008; Winklerprins y Sandor, 2003). El *know-how* se transfiere principalmente por canales informales en el entorno familiar y social, es un conocimiento tácito, es decir del cual generalmente no se es consciente y está adaptado a la realidad local (Reed et al., 2013).

En cambio, el conocimiento científico o *know-why*, es explícito, fácilmente transferible entre expertos en la materia y normalmente extrapolable (Reed et al., 2013), aunque en el caso de la desertificación el marcado carácter local de algunas de sus componentes dificulta o imposibilita la extrapolación de resultados y medidas. El *know-why* está centrado en cuestiones específicas, generalmente factores biofísicos (*soil approach*), mensurables y comparables a través de metodologías testadas, susceptibles de modelización y no siempre evidentes (ej. pH, contenido de C o N, etc.). Este tipo de conocimiento trata de entender los principios y enunciar las teorías en las que fundamentar fenómenos observables (Desbiez et al., 2004; Reed, 2008; Seely y Moser, 2004). Es decir, el conocimiento científico atiende al por qué de fenómenos específicos sin relacionarlos necesariamente con el entorno económico, ecológico y social en el que se desarrollan y sin priorizar soluciones ágilmente aplicables (Thomas, 1997).

La calificación de tierras según su calidad y/o productividad es un buen ejemplo de la diversidad de criterios empleados por usuarios y científicos a la hora de describir fenómenos relacionados con el suelo. A la hora de establecer indicadores de calidad o productividad del suelo, la ciencia atiende a criterios biofísicos como la profundidad, la densidad aparente, la resistencia de agregados, la porosidad, la conductividad eléctrica, el pH, el contenido de materia orgánica y N, la capacidad de retención de agua, etc.

Según la información recogida por otros equipos (ej. Barrera-Bassols y Zinck, 2003; Desbiez et al., 2004; Lima et al., 2011; Mairura et al., 2008; Odendo et al., 2010; Rushemuka et al., 2014) y nuestra propia experiencia, los agricultores atienden a cuestiones más multidisciplinares para describir esta misma cualidad. Enuncian parámetros intuitivos y relacionados con lo que pueden ver o percibir, como son el color del suelo, el color y vigor del cultivo establecido o el rendimiento de la cosecha. También atienden a algunas cuestiones biofísicas como la pendiente, la profundidad, la pedregosidad o la prevalencia de especies no deseadas. Pero además, incorporan una dimensión complementaria, referente a cuestiones puramente prácticas como son el tamaño de la parcela, su distancia respecto a su área base, la accesibilidad de la misma, la respuesta a la aplicación de abonos orgánicos y fertilizantes o el grado de dificultad que entraña el desarrollo de tareas de labranza o cosecha.

Esta dimensión práctica, muchas veces resulta determinante a la hora de implementar técnicas de SLM, sobre todo en situaciones habituales en el sector agrario, como son las rigideces estructurales o la escasez de recursos disponibles para la inversión en nuevas técnicas.

Por ello, la necesidad de combinar el conocimiento tradicional, que incorpora esta componente práctica y sus especificidades locales, y el conocimiento científico es ampliamente reconocida, como uno de los elementos claves para el desarrollo de políticas socio-ambientales eficaces (Odendo et al., 2010; Raymond et al., 2010; Reed, 2008; Reed et al., 2013).

En este sentido el desarrollo de disciplinas científicas integradoras, sensibles a las componentes ecológicas y sociales, así como la promoción del enfoque de las políticas públicas hacia la implementación de medidas prácticas, son dos requisitos indispensables para conciliar investigación y acción, y uno de los grandes desafíos pendientes en la lucha contra la desertificación.

1.3.3. La etnopedología: una disciplina conciliadora

La etnopedología es una disciplina a caballo entre las ciencias naturales y sociales, cuyo objetivo es documentar y entender la percepción, la clasificación y el uso y manejo del suelo/la tierra[14] a escala local (Barrera-Bassols y Zinck, 2003; Sillitoe, 1998; Winklerprins y Sandor, 2003).

Según Barrera-Bassols et al., (2006), la etnopedología recoge y analiza el *know-how* tradicional atendiendo a tres dimensiones: simbólica relativa a los valores, creencias y ritos culturales (*Kosmos*); cognitiva, relativa al conocimiento en torno a la tierra (*Corpus*); y una última dimensión vinculada al uso y manejo (*Praxis*).

Esta disciplina aunque se considera holística, ha ido evolucionando desde enfoques reduccionistas hasta enfoques más integradores. Los trabajos de revisión de información

[14] Anteriormente hemos utilizado los términos suelo y tierra indistintamente, siguiendo la corriente de la literatura científica en inglés que asimila ambos conceptos bajo los términos: *soil* y *land*, aunque en el caso de "*land*" y su traducción al castellano "tierra", este término implica matices de arraigo cultural y una escala de paisaje y territorio.

etnopedológica desarrollados por Barrera-Bassols y Zinck, (2003) y Winklerprins, (1999) identifican tres corrientes: etnográfica, comparativa e integradora.

Los trabajos etnográficos se centran en aspectos culturales relacionados con terminología local para la descripción del suelo, su clasificación o la denominación de prácticas de manejo. Generalmente en este tipo de estudios la información recogida no se compara con información científica (*know-why*).

Los trabajos comparativos son los más frecuentes, y como es nuestro caso, abordan los puntos de encuentro y desencuentro entre el *know-how* y el *know-why*, intentando establecer correlaciones entre las diferentes clasificaciones taxonómicas de los suelos y los tipos de manejo.

Más novedosa es la corriente integradora, que combina *know-how* y *know-why*, a través de procesos participativos que ponen en valor la complementariedad entre el conocimiento científico y tradicional, con la intención de facilitar la construcción de modelos de manejo de los recursos adaptados localmente desde el punto de vista social, cultural, económico y ecológico. La corriente integradora es la más efectiva a la hora de promover el SLM y la que involucra a mayor número de actores para ello.

En las tres corrientes de estudio etnopedológico el peso relativo de las dimensiones *Kosmos Corpus* y *Praxis* está desequilibrado. Es habitual la marginación del *Kosmos*, a pesar de que esta dimensión es imprescindible a la hora de atraer a las comunidades locales y facilitar su participación en la formulación e implementación de estrategias de desarrollo sostenible, ya que es la que representa su identidad cultural.

La mayor parte de los trabajos etnopedológicos desarrollados hasta ahora se localizan en Meso América, la región Andina, la región Subsahariana, África del Oeste, el Himalaya, India y el Sudeste Asiático, mientras que Europa es una de las zonas menos estudiada por esta disciplina (Barrera-Bassols y Zinck, 2003). Se evidencia así la desafección por el conocimiento tradicional en países económicamente desarrollados, donde la tecnificación y agro-industrialización han dado lugar a la devaluación y pérdida de gran parte del conocimiento tradicional, a pesar de que este es determinante en el día a día de los gestores de la tierra. Es por ello que en nuestro trabajo hemos centrado parte de la atención en la percepción y conocimiento de los usuarios de la tierra en torno a la SLM.

1.3.4. Entrelazando el laboratorio y el campo: Agricultural Knowledge and Innovation System

Según Reed et al., (2013) la gestión del conocimiento consiste en generar, recopilar y difundir nuevo conocimiento a la vez que se identifica, se complementa y se aplica el conocimiento ya existente, para alcanzar objetivos concretos. En esta tarea, los servicios de extensión y transferencia agraria deberían ser la pieza clave en el engranaje entre los generadores de conocimiento formal (investigadores) y los usuarios de la tierra y tesoreros de conocimiento tradicional (EU SCAR, 2012).

Inicialmente la gestión del conocimiento se basaba en la transferencia lineal y unidireccional de conocimiento científico hacia los usuarios y tomadores de decisiones (Pascucci y De-Magistris, 2011). En la década de los sesenta, en el ámbito agrario se centró sobre todo en la transferencia de tecnología, con la intención de acelerar la modernización agraria, pero con resultados no siempre deseables debido a la extrapolación de modelos no adaptados a las realidades locales.

Posteriormente se reconoció la necesidad de evolucionar desde modelos unidireccionales hacia modelos bidireccionales, iterativos y con estructura sistémica. Igualmente se apostó por la consideración del conocimiento y las necesidades de los usuarios, y por la colaboración entre investigadores y usuarios para co-generar conocimiento aplicable y no tan sólo explicativo (Le Gal et al., 2011, Pascucci y De-Magistris, 2011; Reed et al., 2013).

En esta línea, el enfoque más novedoso es el promovido por la figura de los *Agricultural Knowledge and Innovation Systems* (AKIS) que facilitan la interacción de los distintos actores involucrados en el sector agrario para la generación de conocimiento innovador, adecuado a las necesidades y prioridades de los usuarios de la tierra y del resto de actores de la sociedad (EU SCAR, 2012) (Figura 11).

Los AKIS se definen como "el conjunto de organizaciones agrícolas y/o personas y las relaciones e interacciones entre ellas para la generación, trasformación, transmisión, recopilación, identificación, integración, difusión y utilización de conocimiento e información, con el objetivo de trabajar sinérgicamente para apoyar la toma de decisiones, la solución de problemas y la innovación en la agricultura" (Röling y Engel, 1990)

Figura 11: Actores implicados en los AKIS. Fuente: EU SCAR (2012).

La puesta en marcha de los AKIS con una perspectiva multifuncional de la agricultura permite no sólo mejorar la productividad agrícola sino dotar también al sector de un valor añadido vinculado con las tradiciones, la conservación del paisaje y otros servicios ambientales (Pascucci y De-Magistris, 2011). Lo que en el caso español es algo especialmente interesante al tratarse de un sector no sólo en crisis económica sino también social (Salazar-Ordoñez y Sayadi, 2011).

En España los principales exponentes de los AKIS deberían ser el Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA) a nivel estatal y los institutos de investigación regionales (ej. IMIDRA en el caso de la CM) y las delegaciones comarcales de agricultura a nivel autonómico.

Según el documento publicado por la EC (2011), para facilitar la implementación de los AKIS, por una parte es necesario conectar los sistemas de conocimiento institucionales (universidades, institutos de investigación, etc.) con los procesos de innovación y los flujos de conocimiento. Y por otra es preciso orientar los AKIS a las necesidades específicas de cada territorio.

Estos dos horizontes fundamentan parte de las líneas de trabajo de este estudio. Principalmente aquellas dedicadas al análisis de la estructura del conocimiento científico en torno a la desertificación y a su comparación con las técnicas de gestión de la tierra implementadas en la zona centro del país. Tras la presentación y discusión de resultados, en el apartado de conclusiones retomaremos este punto, aludiendo a las oportunidades y limitaciones que afrontan investigadores, usuarios y técnicos de transferencia y extensión agraria a la hora de colaborar y construir conjuntamente conocimiento y estrategias de SLM.

2. Objetivos de la tesis

El objetivo general de este trabajo es abordar la desertificación desde una perspectiva socio-ecológica. Este objetivo, más allá de tratar las consecuencias ecológicas y económicas de la degradación de la tierra se centra en aspectos específicos, estrechamente vinculados a algunos de los vectores sociales de la desertificación, poco abordados desde la ciencia.

“Manejo del suelo y desertificación: entre la ciencia y la praxis” parte del análisis de las ambigüedades teóricas y prácticas en torno a la desertificación, para inmediatamente después introducir el marco ambiental, político y económico en el que se están desarrollando las dinámicas *push-pull* de abandono de tierras agrícolas y su conversión a territorios urbanizados. Estas dinámicas, dan lugar a estadios irreversibles de degradación a consecuencia del sellado del suelo. Constituyen uno de los principales agentes degradadores del territorio en España y enraízan en decisiones y factores macroeconómicos y políticos que distan notablemente de las componentes sociales tradicionalmente vinculadas a la desertificación (ej. dinámicas demográficas o sobreexplotación agrícola).

Posteriormente, con el fin de identificar el grado de integración de la dimensión social en el conocimiento científico relativo a la desertificación, se analizan la estructura y las temáticas dominantes en el conocimiento formal (*know-why*) relativo a la degradación del suelo.

El conocimiento formal imperante en materia de desertificación se caracteriza por centrar la atención en factores biofísicos (*soil approach*). La corriente *soil approach* ha calado en las esferas científica e institucional. Sin embargo la lucha contra la desertificación requiere de medidas que atiendan a la componente socioeconómica del problema y para ello es importante desarrollar y fortalecer aproximaciones integrales alineadas con el *land approach*.

Avanzar hacia la consolidación de un enfoque de paisaje-territorio (*land approach)* para la mitigación de la desertificación, pasa por la combinación del conocimiento práctico tradicional y el conocimiento científico y la interacción y retroalimentación entre uno y otro. Con esta meta, la última parte de la tesis se dedica a la identificación de los encuentros y desencuentros entre el conocimiento formal (*know-why*) y el saber hacer tradicional (*know-how*) en materia de gestión del suelo.

Siendo conscientes de la magnitud multiescalar y multidimensional de la desertificación, definir los objetivos específicos de este trabajo supuso un intenso ejercicio de delimitación para poder abordar las cuestiones anteriormente mencionadas a través de tres objetivos secuenciales:

Objetivo 1. Análisis de los agentes causantes de la desertificación en España.

La identificación de los agentes causantes de la desertificación y la implementación de medidas concretas y eficaces para su mitigación, se ve empañada por la incertidumbre de la definición de desertificación más acuñada. La equiparación de causas antrópicas y naturales, la no distinción entre procesos activos y pasivos o las contradicciones en cuanto a la reversibilidad del fenómeno, enmascaran la importancia de algunos agentes degradadores, como es el caso de la expansión urbanística y dificultan la toma de decisiones y la ejecución de acciones concretas respecto a ellos.

Objetivo 2. Análisis de los enfoques y temáticas prioritarias en el estudio científico (know-why) de la desertificación a escala global y en los casos de estudio español y argentino.

Asumiendo la existencia de un proceso de maduración y concienciación en torno a la interdependencia de los fenómenos naturales y sociales, nos propusimos identificar el peso relativo de las aproximaciones holística (*land approach*) y reduccionista (*soil approach*) en el estudio científico de la desertificación. Dicho análisis se desarrolla a escala global, así como a través del estudio de dos casos, para poder evaluar la importancia de algunos elementos locales y también por el interés de la comparativa entre dos países con relativa afinidad sociocultural pero con importantes diferencias económicas y ambientales, en los que la desertificación es un problema preocupante.

Objetivo 3. Análisis del conocimiento tradicional y las percepciones relativas al suelo e identificación de especificidades y complementariedades entre el know-how y el know-why en la zona centro de España.

Reconociendo la relevancia del papel de los usuarios de la tierra en la conservación y manejo sostenible del suelo y en la lucha activa contra la desertificación, se abordan el conocimiento y las prácticas tradicionales de gestión de la tierra en la comarca agraria más importante de la Comunidad de Madrid, la Comarca de Las Vegas. Inmediatamente después, a través del análisis de la percepción de los usuarios en relación al uso de cubiertas vegetales en viñedos y olivares, trata de contrastarse el grado de integración bidireccional entre el saber hacer tradicional y el conocimiento científico.

Cada uno de estos objetivos específicos se desarrolla en más detalle en los capítulos de resultados indicados en la Figura 12.

Figura 12: Cuadro de correspondencia entre los objetivos específicos y los capítulos de resultados de la tesis.

3. Metodología general

“Manejo del suelo y desertificación: entre la ciencia y la praxis” propone una aproximación de lo general a lo particular. Aborda el fenómeno de la desertificación a través del estudio del caso español y va ajustando paulatinamente el enfoque hacia el conocimiento científico[15] (*know-why*) y el conocimiento tradicional (*know-how*) de la cuestión, así como hacia la identificación de encuentros y desencuentros entre uno y otro.

Se trata así de reflejar la complejidad de nuestro tema de estudio desde una orientación holística, que no sólo analiza las causas y consecuencias biofísicas de la desertificación, sino que profundiza en las prioridades de algunos de los agentes implicados en su gestión (científicos y usuarios de la tierra) y en la identificación de los puentes que los unen y las fronteras que los separan. El resultado de este proceso es la compilación de las ocho publicaciones que se presentan en los capítulos de resultados.

Al tratarse de una tesis presentada como compilación de publicaciones la estructura de los capítulos de resultados (Parte II) corresponde consecuentemente al formato de artículos científicos. Los capítulos de resultados incluyen una breve introducción, un apartado de materiales y métodos, una descripción y discusión detallada de los resultados obtenidos y unas conclusiones específicas para cada uno de ellos. Estos capítulos constituyen unidades independientes y comprensibles en sí mismas. Es por ello que este apartado metodológico presenta tan sólo una síntesis y una breve descripción de los materiales y métodos empleados, que quedan detallados en los respectivos capítulos (ver Figura 13).

[15] La aproximación al *know-why* se aborda a través de un análisis a escala global y dos casos de estudio particulares: el caso español y el caso argentino, que son complementarios.

Figura 13: Mosaico fotográfico del trabajo de campo, laboratorio y gabinete. Fuente: Fotografías de Sara Cantador Moreno y María José Marqués Pérez

La revisión bibliográfica es el común denominador de cualquier trabajo científico y lógicamente la recopilación, lectura y análisis de bibliografía es una de las tareas a la que más tiempo se ha dedicado, tanto al inicio como a lo largo de los procesos de redacción y revisión de los capítulos de resultados.

Especialmente importante ha sido esta labor bibliográfica tanto en el caso del capítulo cuatro dedicado a la caracterización del fenómeno de la desertificación en España, como en los capítulos cinco, seis y siete.

En estos tres capítulos (cinco, seis y siete), al tratarse de trabajos centrados en el análisis bibliométrico y de redes, la revisión bibliográfica ha sido fundamental para la consolidación de las muestras de estudio. Más allá de la lectura de las referencias compiladas, se ha procedido a su “disección” para consolidar las bases de datos que nos permitieran rastrear los contenidos de la literatura científica sobre la desertificación, generada en el ámbito global (capítulo cinco) y en los casos específicos de España (capítulo seis) y Argentina (capítulo siete), En los capítulos ocho y nueve se ha prestado especial atención a la identificación de las temáticas abordadas. En base a ellas se han rastreado los enfoques dominantes en el estudio de la desertificación (*know-why*) y a través de los análisis de redes sociales se han definido los flujos de relación existentes entre los diferentes temas.

Cabe señalar que los capítulos cinco y siete son resultado de la colaboración internacional con equipos de investigación interdisciplinares (francés y argentino respectivamente), lo que ha permitido fortalecer la interpretación de los resultados obtenidos y la familiarización con nuevas herramientas de análisis (ej. TETRALOGIE).

En los siguientes capítulos (ocho, nueve y diez) se aborda la importancia del *know-how*, apostando por metodologías sociológicas como las entrevistas abiertas y semi-estructuradas o los cuestionarios para identificar las técnicas de manejo, las percepciones y el conocimiento tradicional arraigado entre los usuarios de la tierra. En estos últimos trabajos ha sido fundamental la colaboración con el equipo del departamento de Investigación Aplicada y Extensión Agraria del IMIDRA, las delegaciones comarcales de agricultura de Aranjuez, Arganda del Rey y Villarejo de Salvanés (Madrid), así como con diversas cooperativas vitivinícolas de la región central.

Además de abordar el saber hacer y las percepciones de los usuarios de la tierra, los capítulos diez y once contrastan este tipo de conocimiento con los resultados de análisis clásicamente científicos.

En el capítulo diez se analizan la cobertura vegetal, las tasas de pérdida de suelo y las propiedades físico-químicas de los sedimentos recogidos (textura y contenido de C orgánico) en cuatro parcelas experimentales sometidas a diferentes tratamientos de cubierta. Estos resultados se discuten considerando las opiniones expresadas por 120 agricultores entrevistados, en relación al conocimiento y uso de técnicas de SLM.

Por su parte, en el capítulo once, el análisis en laboratorio (contenido de materia orgánica y N potencialmente mineralizable, textura, pH, densidad y resistencia de agregados y conductividad eléctrica) de más de 60 muestras recogidas en 31 explotaciones agrarias, ha permitido elaborar un índice de calidad edáfico de las muestras comparable con la calificación que los propios usuarios de esos suelos hacían de ellos. A partir de la comparación del índice basado en el *know-why* científico y la calificación de los usuarios basada en el *know-how*, este trabajo trata de inferir algunas de las áreas de coincidencia y diferenciación entre ambos tipos de conocimiento.

Cada una de las técnicas de recogida de información, así como las metodologías empleadas para su análisis se abordarán en detalle en los respectivos capítulos de resultados, pretendiendo ser este epígrafe metodológico tan sólo una breve introducción a las mismas.

En la Tabla 5 se indican las metodologías empleadas en los procesos de recogida de datos, estructurándolas en función del tipo de información recogida e indicando los capítulos de resultados en los que se trata esta información.

La Tabla 6 recoge los métodos de análisis y herramientas con los que se han tratado las informaciones recogidas y a través de los cuales se han obtenido los resultados presentados. Igualmente en esta tabla la metodología se estructura en función del tipo de información tratada, indicando los capítulos de resultados en los que se exponen los resultados obtenidos.

Tabla 5: Síntesis de las metodologías empleadas para la recogida de datos, según el tipo de información recogida.

TIPO DE INFORMACIÓN			RECOGIDA DE DATOS
Documental	Procedente de usuarios de la tierra	Parámetros físico-químicos de muestras de suelo	
(Cap. 4,5,6 y 7)			Extracción de referencias en Web of Science
	(Cap. 9)		Entrevistas abiertas con 25 viticultores preseleccionados Cuestionarios a 64 viticultores identificados a través del método bola de nieve
	(Cap. 8, 10 y 11)		Entrevistas estructuradas a 120 agricultores, selección de la muestra a través de la combinación de método aleatorio y bola de nieve
		(Cap. 10)	Toma de muestras en parcelas experimentales de olivar con 3 tipos de cubierta vegetal y 1 parcela control- Datos de precipitación (Estación meteorológica automática y Pluviómetro HOBO®); Recogida de sedimentos (Depósitos Gerlach (Gerlach, 1967)); Identificación de cubiertas vegetales (Adobe Photoshop® y observación directa); Textura (método pipeta de Robinson (MAPA, 1994)); Contenido de carbono orgánico (método de oxidación húmeda (Walkley y Black, 1934))
		(Capítulo 11)	Toma de muestras de suelo en 31 explotaciones agrarias de la Comarca de las Vegas- Textura (método pipeta de Robinson (MAPA, 1994) y densímetro Bouyoucos (Bouyoucos, 1962)); Contenido de materia orgánica (método de oxidación húmeda (Walkley y Black, 1934)); Nitrógeno potencialmente mineralizable (Bremner y Edwards, 1965; Keeney y Nelson, 1982); pH (1:2-5 (v/v) (MAPA, 1994)); Conductividad eléctrica (1:5 (v/v) (MAPA, 1994)); Estabilidad de Agregados (método counting number of drops (Imeson y Vis, 1984)); Densidad aparente (método Hg (Johnston, 1945)).

Tabla 6. Síntesis de las metodologías y herramientas empleadas para el análisis de datos, según el tipo de información tratada.

TIPO DE INFORMACIÓN			TÉCNICAS DE ANÁLISIS	HERRAMIENTAS
Documental	Procedente de usuarios de la tierra	Parámetros físico-químicos de muestras de suelo		
(Cap. 5,6y7)			Técnicas bibliométricas	TETRALOGIE; MICROSOFT EXCEL 2013
(Cap. 6 y 7)			Análisis de redes sociales	UCINET 6.414; NETDRAW 2.123
(Cap. 6 y 7)			Índice de diversidad Shannon-Wiener	DIVERSITY 2.2
(Cap. 4,5,6y7)	(Cap. 8,9, 10 y 11)	(Cap. 10 y 11)	Estadística descriptiva	SPSS 19 y 22; PC-ORD 6; STATISITICA 6.0; MICROSOFT EXCEL 2013
(Cap. 6)	(Cap. 8,9 y 11)	(Cap. 10 y 11)	Test de hipótesis-paramétricos y no paramétricos	
(Cap.6 y 7)	(Cap. 8,9 y 11)	(Cap. 11)	Análisis multivariantes-ordenación (análisis de componentes principales); clasificación (clusters)	
	(cap. 8, 10 y 11)	(Cap. 10 y 11)	Modelos de regresión	

PARTE II

Capítulos de resultados y discusión

Como se ha mencionado anteriormente esta tesis se presenta como compilación de artículos científicos, por lo cual este apartado incluye ocho epígrafes de resultados, tal y como han sido publicados en *Journal of Arid Environments* (capítulo 4) y *Land Degradation & Development* (capítulos 5, 6, 7 y 9); otros dos epígrafes correspondientes con trabajos en proceso de revisión en *Society and Natural Resources* y *Soil & Tillage Research* (capítulos 8 y 10, respectivamente) y un último manuscrito en proceso de preparación (capítulo 11) para su envío a la revista *Agriculture, Ecosystems and Environment*.

04

The case of urban sprawl in Spain as an active and irreversible driving force for desertification

Journal of Arid Environments 90 (2013) 95–102

Contents lists available at SciVerse ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

The case of urban sprawl in Spain as an active and irreversible driving force for desertification

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ARTICLE INFO

Article history:
Received 5 March 2012
Received in revised form
8 October 2012
Accepted 10 October 2012
Available online

Keywords:
Land degradation
Land use change
Soil sealing
Urbanization

ABSTRACT

The United Nations Convention to Combat Desertification (UNCCD) does not distinguish between natural and human drivers, and between active and inherited desertification. Partly as a result of these ambiguities the UNCCD has attracted a low level of international attention. As the Spanish case study shows, this vagueness hinders the implementation of effective strategies to combat this global challenge. Unsustainable agricultural land management is the most blamed desertification agent in Spain but as land use changes trends demonstrate, desertification phenomena are fueled by a push–pull dynamics. Our data indicate that agriculture, rather than being a desertification agent, is a victim of a set of social and economic conditions leading to its abandonment and/or transformation in urban land, becoming irreversibly degraded by soil sealing. From 1975 to 2008, half a million ha of former agricultural land has been made available for development. Urban sprawl has become the most active desertification agent in Spain.

1. Introduction

The Rio Conventions (Climate Change, Biological Diversity and Desertification) have followed different paths in terms of social and political support (Geeson et al., 2003; Najam, 2006) and investment (Stringer, 2008). Based on these criteria the United Nations Convention to Combat Desertification (UNCCD) has been considered the 'Cinderella' of the group (Grainger et al., 2000). A cursory review of the number of citations referred in the ISI Web of Knowledge® using the keywords 'Climate Change', 'Biodiversity' and 'Desertification' for the period 1990–2010 supports this observation (Fig. 1).

A possible reason for this difference is that the Climate Change and Biological Diversity Conventions are meant to address global phenomena, whereas the UNCCD restricts itself to arid, semiarid and sub-humid regions, although the economic and social drivers and consequences of desertification transcend these climatic zones and have global impact (Geist and Lambin, 2004). In spite of the fact that desertification occurs in all continents except Antarctica, the UNCCD focuses on developing regions (Rubio and Recatalá, 2006) with special emphasis in Africa, which appears explicitly mentioned in the Convention's title.

Moreover, the three Conventions differ in the handling of drivers for these global challenges. The Convention on Biological Diversity focuses on human responsibility in what is called 'the sixth extinction' (Wake and Vredenburg, 2008). The United Nations Framework Convention on Climate Change goes to great lengths in differentiating natural from anthropic influences in climate change processes, giving emphasis to the latter. However, the UNCCD mixes climate and human factors without suitably considering the possibility to address each of them. This ambiguity in the definition of the causes, concept and solutions may be caused by the poor attention received by the Desertification Convention when compared with the others. In fact, the UNCCD remains the only 'Rio Convention' that is not well served by the scientific community and lacks the equivalent of an Intergovernmental Panel on Climate Change or the proposed Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services (Thomas et al., 2012).

In this paper we present some consequences of this ambiguity. Globally, the desertification drivers are diverse and often act simultaneously, although some region-specific trends emerge, e.g., in Sub-Saharan Africa, it is chiefly due to overgrazing and intensive

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http://dx.doi.org/10.1016/j.jaridenv.2012.10.014

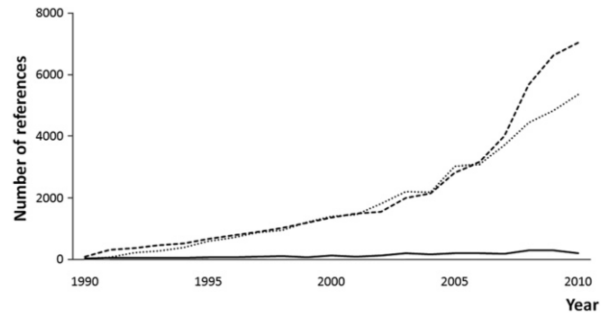

Fig. 1. Number of publications in Internationally Reviewed Journals during the period 1990–2010 based on the keywords ‘climate change’ (- - -), ‘biodiversity’ (• • •) and ‘desertification’ (——). Based on data obtained from ISI Web of Knowledge®.

cropping patterns; in Asia and Middle East salinization processes are frequent; Central Asia suffers overdrafting of groundwater and poor cropping practices; South America experiences also overgrazing and deforestation. Agricultural practices are responsible for desertification processes in North America and Australia. In the northern Mediterranean region desertification is more related to urban development and land abandonment, Spain being “… representative of land change processes in Mediterranean member state of the European Union” (Stellmes et al., 2013, page 1) and an example of an affected developed country where the current main driver differs from the classical demographic and agricultural pressures.

2. What is desertification?

Desertification was popularized in 1949 by Andre Aubreville (Herrmann and Hutchinson, 2005), having since been subject to an intense debate. This debate is the result of three converging issues: the ambiguity over the relative importance of natural versus human factors behind it (Geist and Lambin, 2004); the degree of reversibility of ecological dynamics in affected areas (Herrmann and Hutchinson, 2005) and the total area and population affected by desertification (Verón et al., 2006).

The most commonly accepted definition is the official UNCCD: ‘desertification means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities’. However, this definition has been criticized for being “too vague and ambiguous” (Juntti and Wilson, 2005).

Aridification and desertification are independent phenomena that can nevertheless retrofit each other. Aridification is a long term process typical of water-stressed lands by which a region is gradually becoming drier. It is a natural process not intrinsically negative, although limiting ecosystem’s primary productivity and therefore its life-supporting activities. Desertification is considered in this paper as the consequence of inappropriate land management in arid, semiarid and dry-sub humid ecosystems. It can take place with or without aridification, but it requires degrading anthropic activities, that tend to be magnified under aridification (Yassoglou and Kosmas, 1999). Desertification is normally understood as a *process* (Thomas and Middleton, 1994) but can also refer to an *outcome* or final state (Hill et al., 2008). This distinction has important consequences in the analysis of the reversibility of desertification and its perception as an irreparable ending stage.

The ambiguity regarding land area and population is also implicit in UNCCD’s assessment of potentially vulnerable areas that includes all arid, semiarid and dry-sub-humid regions. According to these criteria, desertification would affect 41% of the continental land and over 2 billion people (Millennium Ecosystem Assessment, 2005). These figures do not take into account different levels of vulnerability depending on demographic trends and the type and scale of economic activities. However, as Rubio and Recatalá (2006) point out, at a local scale desertification is determined by factors such as soil type, land physiography, use and management, thus rendering these global figures intractable.

Therefore, neither the drivers nor the impacts of desertification in developing and developed countries are the same. Moreover, their ability to respond to desertification challenges differs due to the very different technical, economic and human capacities between countries. Hence, combating desertification is a contextual activity linked to the spatial, temporal, cultural, socioeconomic and environmental conditions of each region (Warren, 2002).

3. Desertification in Spain

3.1. Background and magnitude

Over two thirds of the Spanish territory is under dry sub-humid and semiarid climatic conditions. Some areas experience erosive events typical of the Mediterranean climate. These erosive processes are also reinforced by a complex geomorphology, with a slope average of 4.8% and an average altitude of 660 m asl (compared with the European average of 297 m). Moreover, Spain has a population density of 92 inhabitants/km^2, low compared with the European average of 116 inhabitants/km^2. Most of it concentrates along the coast and the two main river valleys (Guadalquivir and Ebro) as well as the inland capital, Madrid. This results in a dual, polarized settlement pattern with large and sparsely populated territories that coexist with dense urban areas. Climate, geomorphology and population settlements therefore combine to result in several characteristics that make the country prone to desertification.

The Spanish National Action Program to Combat Desertification (NAP) estimates that 2.03% of the territory is under very high risk of desertification and 15.82% under a high risk. As can be observed in Fig. 2, Spain is the most vulnerable country to desertification in the European Union (EU).

Nevertheless, these figures should not be taken at face value because they involve a high degree of uncertainty derived from the wide variability of techniques for monitoring and assessment that are employed. Thus, biophysical factors tend to be the most important indicators to assess the area affected by desertification. A commonly accepted indicator is erosion. The Universal Soil Loss Equation (USLE) is frequently employed to assess this indicator, and it has been widely used in Spain for decades (Martínez-Fernández and Esteve, 2005). However, this model was calibrated to estimate erosion rates in agricultural plots and several scientists consider that can lead to overestimations of data if it is used in other contexts. In fact, some studies demonstrate that USLE yields erosion rates 10–60 times larger than those obtained with direct measurements (Martínez-Fernández and Esteve, 2005). Extrapolations, climatic differences and soil variability require caution when dealing with erosion models (Trimble and Crosson, 2000). In spite of these shortcomings, the results of this USLE-based model and others similar to it feed the thematic cartography and strategies of the Spanish Administration both at regional (e.g., Forestry Plan of the *Comunidad Valenciana*, a very vulnerable region in Spain) and national levels (NAP). This is why we can reasonably assume that real desertification figures are less than those officially reported.

Further from erosion, the above mentioned NAP is based on indicators such as aridity index, fire affected areas and aquifer overexploitation. Socioeconomic indicators related to land use

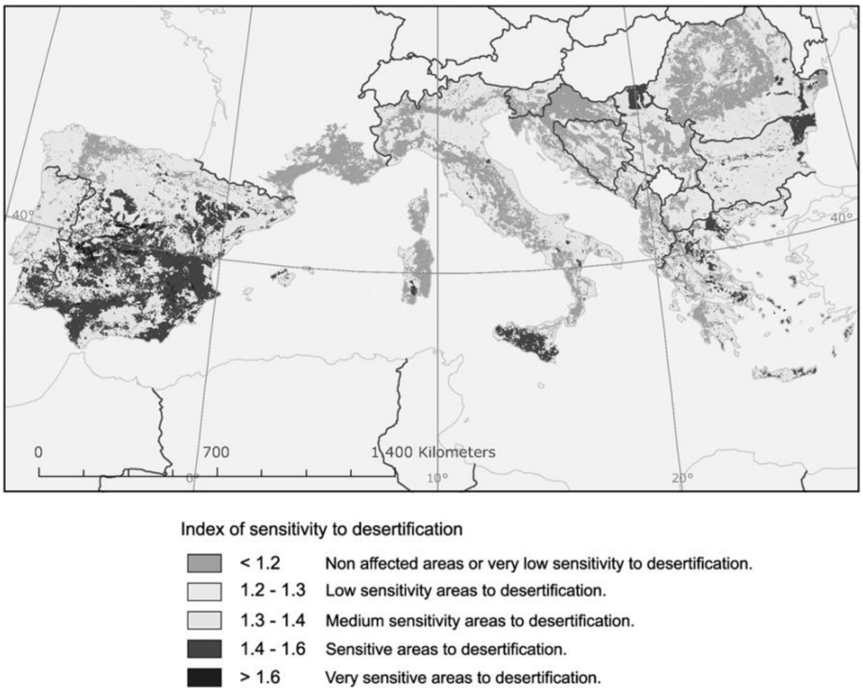

Fig. 2. Index of sensitivity to desertification (SDI) modified from Domingues and Esteve (2008).

changes (urbanization, agricultural practices, land abandonment, etc.) crucial to understand desertification are missing. The Spanish NAP recognizes the need to incorporate some of these and other socioeconomic indicators such as depopulation, population aging and abandonment of traditional management practices. However, they are not elaborated and so far have not been applied to estimate desertification risks and rates.

3.2. *Active and passive desertification*

The impact assessment of land use change and overexploitation sustained over long periods should consider the actual land degrading power and the reversibility degree of the changes induced. Some changes are permanent, and even those that can be reversed may be present over long periods affecting soils, the hydrological cycle and whole ecosystems (Bellot et al., 2007).

According to Yassoglou and Kosmas (1999, page 28) ‘irreversible desertification is the terminal stage of accelerated erosion that has permanently reduced the rootable space and the water storage capacity of the soil below the tolerance levels of economically and environmentally valuable plants’. Blum (2009, page 112) considers irreversible impacts as ‘these damages that cannot be reversed in a time span of about 100 years or four human generations’. The reversibility of desertification depends on the intensity and duration of causal agents, the environment where it takes place, and the time and costs involved.

Taking into account the presence of desertification drivers we can distinguish a passive and active desertification. Passive desertification results from the action of desertification processes important in the past but that are no longer operating. Passive desertification may be a permanent feature in the landscape (in case of high irreversibility) or may be a transient stage to recovery. Active desertification results from processes currently operating and that may eventually lead to a reversible or irreversible stage.

The Spanish NAP does not make this distinction, lumping together all kind of situations in the desertification risk assessment. This is however an important aspect to be taken into account when envisaging strategies to combat desertification. For example, the Spanish NAP emphazises inappropriate agricultural practices as the main reason for desertification. While this can sometimes be true, it is also true that many times it corresponds to passive desertification, that is no longer operating and which has different degrees of reversibility. At the same time NAP it is not paying sufficient attention to urban sprawl, a major active and highly irreversible desertification driver. We explore implications of these biases in the following sections.

Bearing this in mind two different perspectives should be considered when addressing desertification: If we are dealing with passive desertification, land restoration would be prioritized, but if active desertification is occurring, active agents must be identified and controlled.

3.3. *Agriculture and desertification*

Desertification in Spain used to be linked to overexploitation and land use changes, especially in the agricultural sector. However this sector plays a dual role. On one hand it can be a desertification agent, *active* in areas under unsustainable agricultural management, and *passive* in abandoned areas where agriculture has been so intensive that soil degradation cannot be reversed. On the other hand, abandoned agriculture can release land for natural re-vegetation and afforestation, thus reversing former degradation processes.

In recent decades agricultural land release has predominated. The rural exodus and the Common Agricultural Policy (CAP) have led to intensification of most productive lands and the abandonment of marginal lands (MacDonald et al., 2000). Farmland has decreased more than 3.5 Mha (Fig. 3). At the same time forest land

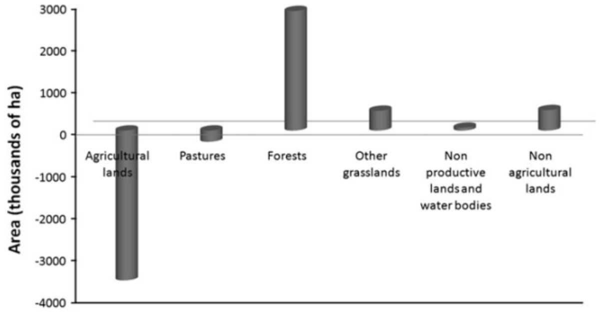

Fig. 3. Land use changes in Spain from 1975 to 2008. Based on Spanish Agricultural Yearbook (Ministerio de Medio Ambiente, Medio Rural y Marino, 1976–2009).

increased 2.85 Mha, due to land abandonment followed by natural regeneration and/or re/afforestation as a result of expansive forestry policies, a trend corroborated by the second (1986–1996) and third (1997–2006) national forestry inventories. Moreover, non-agricultural land has increased in half a million ha, most of them available for development leading to active desertification due to urbanization.

4. Urban development and desertification in Spain

4.1. Urban development as a land degradation factor

Urban development implies a direct physical cover of the built land, as well as induced land use changes in neighboring territories to supply goods and services (Table 1). The first is known as 'soil sealing' (Burghardt, 2006).

There are two basic models of urban development: compact cities and extended-mixed use urban developments (Daneshpour and Shakibananesh, 2011). The compact cities with high density populated areas, could be considered more sustainable as they minimize land occupation for other uses, reduce energy and water consumption, air pollution, automobile dependence, while also avoiding the squandering of biomass on paved streets, driveways and parking lots. The extended mixed-urban development refers to low density populated areas, significantly increasing geographical spread or urban (sealed) land. Usually identified as "urban sprawl", the extended mixed-urban development is planned mainly for houses but it also requires land for schools, office buildings, shopping areas, sport facilities and industrial uses, as well as roadways and parking lots.

In any case, urban soils are totally or partially separated from the atmosphere by sealing because of covering with impervious or low permeability layers. During construction, soils are often desurfaced, mixed and compacted (Pouyat et al., 2007). Soil bulk density increase is not only confined to the topsoil but penetrates to a considerable depth in the subsoil and decreases soil porosity (Lehmann and Stahr, 2007). Not all the settlement area is affected by soil sealing and compaction. Paved surfaces by asphalt, concrete or similar materials and buildings clearly fall under the definition of impervious surfaces or sealed soils. However it is not easy to classify other kind of surfaces such as pervious asphalt or mixed settlements with parks or gardens. Obviously urban areas have different percentages of impervious surface, e.g., high density residential use tends to have over 75%; low density residential ranges from 18 to 45%; industrial areas, 55%; commercial areas, 64%. These figures are certainly high compared to croplands, pastures or forests with less than 5% of impervious surface (see the reviews by Exum et al., 2005; Nowak and Greenfield, 2012). Soil having more than 80% of impervious surface is usually regarded as having suffered a strong environmental impact, being classified as "sealed" (Di Gregorio, 2005).

The concentration of people has advantages, offering opportunities like employment, health and education (Portnov and Safriel, 2004). It has also been considered as a cause of environmental degradation, mostly regarding pollution and resource depletion (Marcotullio et al., 2008). However, urban areas are not so often related to land degradation, particularly in drylands, where the effects of population density, energy use, heat-trapping and water demand and constraints such as drought periods and flood events are much greater than in temperate climates.

The large amount of water needed by cities is commonly provided by reservoirs and groundwater sources affecting streams and aquifers, which in the case of drylands may be particularly negative due to their low replenishment capacity. These urban developments have to increase groundwater extraction or to transport water from surrounding or distant regions which also result affected. Coastal areas face in addition the risk of salt water intrusion and soil salinization in case of severe aquifer overexploitation.

Furthermore, soil sealing decreases water infiltration and evaporation rates and enhances rainfall runoff. This might negatively influence soil moisture patterns and hydrological dynamics of watersheds and wetlands (Salama et al., 1999) because the surface and groundwater interactions (discharge/recharge points) are altered. At the same time the temporarily soil water storage capacity is lost, leading to a decline in the water retention and filtering capacity of soils. The water held in the soil is available to plants being therefore able to deal with droughts or water constraints; it is also available to crops making them less dependent on irrigation, what in turn reduces soil salinization.

Some simple figures can help understanding this impact: a Cambisol, the most widespread soil in the European Union and in Spain, usually has a bulk density of around 1.5 g cm^{-3}. Its volumetric water content can reach up to 0.4 m^3 m^{-3} soil (40%) in saturated conditions, so it can potentially hold up to 400 L of water per m^3 of soil. This is a significant percentage of the yearly rainfall –

Table 1
Irreversible effects on soil integrity and socio environmental changes linked to urbanization.

Direct consequences
• Top soil loss by physical remove or sealing (Blum, 2009).
• General decrease in soil moisture content, the water regime of the underlying soil is severely altered, there is a lowering of water tables (Scalenghe and Marsan, 2009)
• Rainwater infiltration is impeded, resulting in high runoff rates and risk of flooding as well as water loss in regions where water is a scarce resource (Barron et al., 2011).
• Increased connectivity leading to higher runoff and erosion processes (Frey et al., 2009).
• Increase of evaporation rates in urban areas, sealed with asphalt, cement or other dense materials (Blum, 2009).
• The ability to regulate water cycles decreases in urbanized river basins (Burghardt, 2006).
• Rise of temperature due to heat accumulation in buildings (Grimm et al., 2008).
• Increasing waste and emissions rates (Chen, 2007).
• Decreased soil biodiversity (Byrne, 2007; Pickett et al., 2008).
• Ability of soil to act as a carbon sink is affected (Powlson et al., 2011).
Associated socio-environmental changes
• Emergence of water and land conflicts between urban and agricultural sectors due to growing demand of urban areas (Pavón et al., 2003).
• Dual process of abandonment of marginal lands and intensification of high quality lands leading to disappearance of traditional landscapes (Detsis, 2010; Rubio and Recatalá, 2006).
• Social disruption and loss or rural traditions (Van Eetvelde and Antrop, 2004).

the average annual rainfall in Spain is 648 mm, falling below 500 mm in dryland Spain.

At least 50% of open space is required to maintain satisfactory rates of water infiltration (TCB, 2010). Low water permeability in urban environments leads to an increase in surface runoff and to a drop in groundwater recharge rates. Moreover, in case of heavy precipitation the sewer systems of sealed urban areas are not capable of collecting the total amount of surface runoff resulting in an increased flood risk. Haase and Nuissl (2007) found that once the share of impervious land exceeds 60%, runoff control drops 3–4 times and wherever it is >80%, run-off control drops between 5 and 6 times. For instance, in southern European Mediterranean basins, up to 75% of the precipitation in summer storms, evaporates and re-circulates within the Mediterranean drainage basin due to sealing (Millán, 2010). The interconnection of impervious surfaces plays an important role in this process since they can act as canals to transmit runoff or sediments from site to site. Moreover, peri-urban areas frequently lack convenient drainage systems and rely on natural drainage channels, resulting in localized flooding with even light rainfalls.

The water balance impact of soil sealing on evapotranspiration leads to lack of evaporative heat loss, temperature regulation is compromised, and the cooling benefit of natural soils is lost. On one hand, urban areas create their own microclimate (Pauleit et al., 2005) and overheating of sealed areas has negative costs for health and energy consumption that might be more severe in semi-arid or arid regions. On the other hand, the precipitation pattern depends on evapotranspiration rates (Kravcík et al., 2007); the loss of vegetation cover and evaporation due to soil sealing may contribute to changes in local weather patterns, becoming a key issue to avoid undesirable changes at local scale in dry regions.

Finally, the limited exchange of gases and water in sealed soils has consequences in soil biodiversity (Löfvenhaft et al., 2002), which are critically affected if not destroyed (Byrne, 2007). Some key processes are impaired (Pickett et al., 2008), for example, biogeochemical transformations of C and N in sealed soils are only marginal (Lorenz and Lal, 2009). The above mentioned climatic, edaphic and geomorphological features of Spain make it particularly vulnerable to this type of factors.

4.2. The driving forces of urban development

Releasing land from agriculture to urban uses has been achieved through push–pull dynamics (Table 2) strongly related to the economic and policy contexts (Brauch, 2003).

Arguably the low and decreasing profitability of Spanish farming (especially in rain-fed areas) is the single most important push factor. Since 1996, the agricultural added value has stagnated or even declined (Fig. 4). This has been compounded by the

Table 2
Push–Pull factors influencing agriculture land releasing for urban development in Spain (CAP: Common Agricultural Policy).

Push phenomena	Pull phenomena
Declining soil fertility	Priority of water supply to urban and tourist areas
Scarcity of water for agricultural uses	Profitability of real estate and scarcity of alternative investments
Lack of profitability of farming	Fast increase of urban land prices
Relative depreciation of agricultural lands	Tax incentives for housing acquisitions
Promotion of farmland set aside by CAP	Aggressive urban development policies
Weak environmental considerations in land use policies	High salaries of the building and real estate sectors
Rural exodus/Rural-urban migrations	Growth of urban and touristic areas

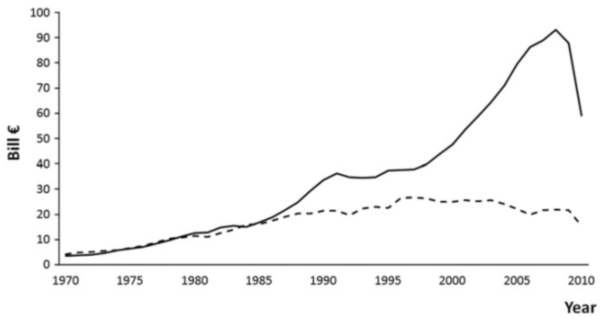

Fig. 4. Gross Domestic Product (GDP) trends for urban and agricultural sector from 1970 to 2010 (Units: Billions of constant euros of year 2000; Added value of urban sector (———), added value of agriculture (- - -). Source: Based on CEPREDE and INE databases.

difficulty of small scale agriculture to compete in globalized markets (Geeson et al., 2003). It has also been influenced by soil degradation and subsequent loss of productivity. The agricultural sector has offered a dual response to face this situation: on one hand, a significant increase on average farm size (from 17.8 ha in 1972 to 32 ha in 2007) and concentration of activities on high quality and/or irrigated land; on the other hand, the already mentioned abandonment of marginal lands.

These push factors are dwarfed by the magnitude of some pull drivers like industrialization and more recently, urban development, as well as the increasing demands of a booming tourist sector.[2] The conversion from agriculture to urban land tends to generate huge profits. In 2005–2007, at the peak of the Spanish construction boom, average prices of urban land were 260 times higher than those of agricultural land (EUROSTAT; Ministerio de Fomento). This explains why large-scale land conversion in Spain has affected not only marginal but also high quality (even irrigated) agricultural lands.

The construction boom attracted surplus labor from rural areas contributing to a strong shift in the economic structure. The agrarian sector shrunk from 19.97% of employment and 8.72% of GDP in 1976 to 4.45% and 2.49% in 2006 (CEPREDE; Ministerio de Hacienda y Economía). The construction sector followed the opposite trend until the recent economic crisis, as can be seen in Fig. 4.

In fact, for over two decades the construction sector has acted as an investor refuge given the generous tax rebates and the limited options offered by more conventional stock-exchange investments like industry or technology. This has led to a vicious circle of construction-based development with a high environmental cost notably as land occupation and soil degradation. It is worth mentioning that these push–pull phenomena are unidirectional, at least in what land and soil are concerned since, once developed, the land loses the potential for other uses and the soil is irreversibly degraded.

Agricultural land, forest and other natural areas face different regulatory frames than urban areas. The inconsistent and frequently conflicting objectives of urban, agricultural and environmental policies favor the present situation characterized by an emphasis on development and consequently land degradation. This reached its pinnacle in the National Land Law of 1998 (*Ley 6/1998*,

[2] Spain is the third touristic destination in the world receiving 51.5 millions of tourists per year (period 2000–2005) (INE http://www.exceltur.org/), 52.7 million in 2010. Tourism contributed to 10.2% of Spanish GDP in 2010 (INE http://www.exceltur.org/).

Table 3
Relative variations of land uses (agricultural, forest and urban) in the last decades for big EU countries. Source: (FAOSTAT) (2008, 2006 y 1990), (CORINE LAND COVER) (2006–1990) and Global Forest Resources Assessment 2010 (FAO, 2010). (n.a.: Data not available).

	% Agricultural land			% Urban land		% Forest land		
	2000–1990	2006–1990	2008–1990	2000–1990	2006–1990	2000–1990	2005–1990	2010–1990
France	0.71	0.74	0.26	0.21	0.36	1.48	2.13	2.57
Spain	−3.69	−5.12	−5.67	0.33	0.60	6.26	6.86	8.60
Sweden	−0.31	−0.41	−0.47	n.a.	n.a.	0.24	2.05	2.05
Germany	−1.09	−0.97	−0.78	0.44	0.57	0.93	0.93	0.93
Poland	−1.29	−6.36	−5.63	0.04	0.08	0.57	1.02	1.46
Finland	−0.25	−0.03	−0.04	n.a.	n.a.	1.69	0.79	0.79
Italy	−2.28	−6.81	−7.32	0.25	0.41	2.59	3.88	5.18

de 13 de abril, sobre Régimen de Suelo y Valoraciones) by which any land without specific environmental protection was liable to be urbanized. Moreover, development has been an important source of funding for local administrations through different types of taxes.

Several recent forest and land legal attempts (*Ley de Montes, 2006 and RD 2/2008, New Land Law compilation, 2008*) have tried to mitigate the real estate speculation but they have proven to be insufficient and have arrived too late. Consequently socio-economic and environmental impacts of urban sprawl and tourism make Spain a stunning case study in Europe (Auken, 2008).

4.3. The magnitude of urban development

Urban sprawl occurs at the expense of rural areas. It normally responds to economic and demographic expansion, providing for the required infrastructure, housing and industrial land demand. The development of the Mediterranean coast epitomizes this process in the Spanish case. López Bermúdez (2008) highlighted that urbanization and the consequent soil sealing in the first kilometer of the Spanish Mediterranean coast increased by 34.1% from 1987 to 2000, and this conversion even accelerated during the 2000–2006 period. A similar process has taken place near large cities.

Table 3 compares land use changes in large European countries (more than 250,000 km^2). Spain is the second country in relative terms after Italy releasing agricultural land, and the first in absolute terms. At the same time it is also the EU country with the highest forest recovery rates in relative and absolute terms. This positive phenomenon, due precisely to the large amount of marginal agricultural land released and to the way in which forest cover is defined (that includes wooded lands in early successional stages) may contribute to reduce the risk of desertification.

As can be seen in Table 3, Spain is also the most affected country by urbanization (both in absolute and relative terms), with a 0.6% relative increase during the study period. While Germany also shows high rates of urbanization, this is due to infrastructure development and economic conversion following reunification. In Spain, however, the increase in urban area not only reflects the expansion of infrastructure and the above mentioned development around large urban centres and coastal areas, but also development of second homes even in regions suffering depopulation and economic stagnation (GeoVille, 2009).

This paradox of intense urbanization of depopulating areas, without equivalent in other EU countries, is one of the most astonishing facts of Spanish urban sprawl and is also accompanied by a number of 'records'. In 2004, at the peak of the urbanization process, more than 786.257 new homes projects were approved in Spain (Ministerio de Fomento), an amount equivalent to the combined new homes approved in France, Germany and United Kingdom in that year (Rodríguez López, 2005). Spain also holds the EU record of km of highways per inhabitant (Segura, 2005).

In short, Spain shows fast and opposite processes of land use change following land abandonment: forest recovery and urban sprawl. The latter, under the prevalent Mediterranean climate conditions has led to high desertification risks that are not viewed with sufficient importance. These coincide with the syndrome of rural exodus, overexploitation and urban sprawl/mass tourism identified by Stellmes et al. (2013).

4.4. Future scenarios

The current economic crisis has exploded the construction bubble which has been particularly notorious in Spain. However, while it seems unlikely to come back to urban growth rates of the period 2000–2008, some recent anti-crisis measures suggest that the lessons have not been fully learned and that urban development is still considered a major economic driver. This is exemplified by the recent moratorium[3] to the legally established deadline to start construction in land approved for development, with the intention to prevent its reversion to rural land and to secure the financial investment already made, or the on-going revision of the Coastal Law to remove any land development obstacles. Likewise, local authority's recent approval of a major tourist resort in an emblematic natural area of Tarifa (Andalusia), or the plan to host the Eurovegas complex in the periurban area of Madrid as the largest European centre of leisure tourism and gambling suggest an inertia of the same development model. All these initiatives have in common large urban projects with their corresponding land degradation, which are being touted as major anti-crisis and job creation steps.

At a global scale, the compounded effect of population growth and its concentration in cities will bring a major push for urban development. UN medium population projections forecast over 9 billion people by 2050, with 90% of the increase taking place in developing regions. By then, two thirds of humanity will live in towns and cities (World Urbanization Prospects, 2012). It is expected that 80% of global urban growth by the year 2030 will occur in Asia and Africa (Martine, 2008).

In the meantime, in both developing and industrialized countries, average densities of cities have been declining quickly (Angel, 2006). This may lead to an expansion of the urban sprawl model. Should this pattern prevail, every new city dweller in developing countries will mean some 160–500 m^2 converted from non-urban to urban land (Angel et al., 2005). The growth of these cities -described as "dynamic, diverse and disordered"

[3] See Decree 20/2011, of 31st December 2011 establishing urgent budgetary, fiscal and financial measures to correct the public deficit (in Spanish) www.boe.es/boe/dias/2011/12/31/pdfs/BOE-A-2011-20638.pdf

(UNFPA, 2007)- frequently takes place as informal settlements and complex patterns of land tenure and land use, pushed by expanding population in a context of poverty and limited resources or in ecologically vulnerable zones (Martine et al., 2008). Under these circumstances water supply, sanitation, electricity or transportation, not to mention social services, are not guaranteed. This affects both ecosystem services as well as the city's ability to responsibly and effectively plan for human wellbeing.

As the Spanish case shows, there is a risk that, further from providing basic human needs, some urban trends in developing countries may reproduce a real state bubble with serious social, economic and environmental effects.

5. Conclusions

The Spanish example helps explain the difficulties faced by UNCCD (when compared with Climate Change or Biological Diversity Conventions) to reach scientific consensus, social acceptance and stable financial support. UNCCD has failed to respond in an appropriate and differentiated way to the natural and socio-economic processes driving desertification. To some extent this weakness is related to the clear dichotomy underpinning the desertification phenomena that can reflect inherited actions from the past but also currently ongoing agents. But it is also the result of a Convention that mixes naturally occurring conditions (arid ecosystems) with humanly induced processes.

Our argument is that anthropogenic factors are the key triggers of desertification and these factors include rural and urban related activities, the latter frequently overlooked in national initiatives and international fora. Thus, it is common to find references blaming agriculture and livestock overexploitation or marginal land abandonment for desertification. However, during recent decades in Spain it has been an uncontrolled and disproportionate urban sprawl what has led to desertification characterized by irreversible soil sealing. Rural to urban land conversion in Spain in the last two decades has been the highest in the EU induced by a push–pull dynamics. The release of agricultural land (marginal or not) has been matched by socioeconomic and policy contexts that have resulted in an unprecedented urban sprawl leading to desertification and loss of ecological functions.

While this is true, it has happened in a context of forest land expansion, also from abandoned agricultural land. This underscores the need to advance in common methods and standards that allow to recognize human influence in natural processes and to identify paths leading to different scenarios of land recovery or land degradation.

The Spanish case is relevant at an EU level, but can also throw light on urbanization processes taking place in developing countries. This may help refocus the desertification debate stressing its human-induced nature while also explaining why it is important to pay attention to an ever-growing urbanization as an active and irreversible desertification agent. In this sense it is important to outline the need for spatial planning strategies, appropriate urban design tailored to regional-specific conditions, and accompanying policy and legal instruments in order to minimize the negative impacts urban development.

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First appraisal of the current structure of research on land and soil degradation as evidenced by bibliometric analysis of publications on desertification

LAND DEGRADATION & DEVELOPMENT
Land Degrad. Develop. **26**: 413–422 (2015)
Published online 19 March 2015 in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/ldr.2351

FIRST APPRAISAL OF THE CURRENT STRUCTURE OF RESEARCH ON LAND AND SOIL DEGRADATION AS EVIDENCED BY BIBLIOMETRIC ANALYSIS OF PUBLICATIONS ON DESERTIFICATION

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Received: 24 November 2014; Accepted: 24 November 2014

ABSTRACT

Fighting land and soil degradation is in the mandate of the United Nations Convention to Combat Desertification (UNCCD). However, it is often suggested that a lack of scientific guidance has resulted from inadequate institutional mechanisms to channel science into UNCCD decision making, rather than from a lack of research on UNCCD-related issues. To explore this issue in more depth, this study explores the corpus of international publications dealing with land and/or with soil degradation. We extracted information from the 'Web of Science'. By applying bibliometric methods and data mining, we mapped the key actors (laboratories, teams, and institutions) involved in research on land and on soils. Several filters were applied to the databases in combination with the word 'desertification'. The further use of text mining software (Tetralogie®) allowed the analyses of similarities and differences between keywords, disciplines, authors, and regions and identifies obvious clusters. Understanding interconnections between these clusters ultimately allowed a first diagnosis of some of the strengths and weaknesses of the scientific community dealing with desertification. This type of detailed analyses can contribute to clarify the scientific landscape at large, and further in-depth studies could lead to improvements in the way scientific advice is channeled into the UNCCD.

KEY WORDS: land degradation; soil degradation; desertification; bibliometrics; text mining; UNCCD

INTRODUCTION

Global environmental issues are dealt with at the international level through multilateral environmental agreements (MEAs), where decisions should be based on the most recent scientific results, and at the same time on consensus among the countries that are party to those agreements ('Parties').

Two of the Rio environmental conventions already have the support of a mechanism to provide them with well-grounded and policy-oriented science-based recommendations: the United Nations Framework Convention on Climate Change can benefit from the Intergovernmental Panel on Climate Change on climate issues, the Convention on Biological Diversity will receive advice on biodiversity issues from the Intergovernmental Platform on Biodiversity and Ecosystem Services. The United Nations Convention to Combat Desertification (UNCCD) has recently been searching for ways to design and implement a mechanism to enable scientific advice to strengthen its actions (Thomas *et al.*, 2012). The current debate about how to achieve this has been stirred by different questions such as the following: should such a mechanism serve only the UNCCD? Should it deal with land degradation globally or should it focus on drylands only? (e.g., UNCCD, 2012). Whatever direction is taken, an advisory mechanism on desertification will need to consider other initiatives under development such as the Global Soil Partnership (Terms of Reference of the Global Soil Partnership, 2012; Montanarella & Vargas, 2012) and will need to gain a stronger over view of the landscape of scientific research in order that it can make best use of the knowledge at large.

In an attempt to advance knowledge in this area, we have undertaken a quantitative analysis of the papers published on desertification to shed light on (a) the current features of the scientific community working on this issue, (b) whether trends in research on land degradation and desertification can be distinguished, and (c) the significance of terminology, that is, whether it makes a difference to consider 'soils' or 'land' in this context.

The third part of our analysis is particularly important. We raise the hypothesis that such a distinction between 'soils' and 'land' might not be a purely semantic or academic exercise, but that it could have consequences for the way sustainable management is studied, discussed, promoted, and implemented by decision makers. Soil is embedded in the

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landscape, its quality and conservation is linked to other environmental components (Louwagie *et al.*, 2011). The term 'land' in its broader sense is defined as 'a portion of the Earth's solid surface distinguishable by boundaries or ownership' (cited from www.Meriam-Webster.com consulted 20 October 2013). Sustainable Land Management has been defined at the 1992 UN Earth Summit as 'the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions'. Soil can be defined as 'the superficial unconsolidated, biologically active, porous medium that has developed through physical weathering and biological processes in the uppermost layer of the Earth's crust', cited from www.Meriam-Webster.com. When comparing these definitions, their differences are striking: land and its sustainable management are considered more as a multidimensional concept, including rocks, soils, and everything they carry (vegetation, animals, water bodies, infrastructures, landscape, and time), including environmental change driven by human interferences (Fleskens & Stringer, 2014). Soils on the other hand are considered part of land, mainly comprehended in biophysical terms through their vertical dimension (depth).

We could argue that a focus on land is approaching the issue of degradation and sustainability at the landscape level, whereas studying soil degradation will usually imply a more local and focused analysis. The aforementioned definitions suggest that land and soil are intrinsically bound to each other. Consequently, they cannot be regarded independently from the scientific perspective. For example, land degradation caused by the removal of vegetation can have far reaching consequences on soils and soil degradation, which usually impact the landscape level (Stringer, 2008, Bauer & Stringer 2009, Akhtar-Schuster *et al.*, 2011, Thomas *et al.*, 2012, UNCCD 2012).

To decipher the complex production of knowledge around this topic, and to address the other aspects of our overall aim, we opted for the analysis of published information using mathematics and statistical tools. These tools, regrouped under the term of bibliometrics, started to be developed in the 1970s (Pritchard 1969), but they are now a very commonly used set of techniques. The development of large databases of references and their access through the internet, combined with the widespread availability of computers, allows the application of quantitative studies to the literature. The main goals of such studies are, in general the following: (i) analysis of structures and dynamics (search for regularities, such that predictions are possible); (ii) understanding of patterns ('order out of documentary chaos', verification of models, assumptions and so on); and (iii) enhancing the rationale for policies and their design.

In the present case, we are focusing on scientific literature. This subset of the field of bibliometrics is sometimes called 'scientometrics' (de Bellis, 2009). These techniques have been developed and commercially deployed mainly under the influence of the founder of Institute for Scientific Information (ISI) (Garfield, 1955). ISI is now part of the 'Web of Science' (WoS) from Thomson Reuters. Currently, this is the most accessible database for bibliometric analysis.

The present study is an attempt to decipher the questions set out earlier by improving understanding on the current links between teams working on aspects of 'land' and 'soil'. Our analyses may also indicate important related scientific disciplines in which scientists are working on desertification. This is important in advancing the flows of scientific knowledge into the UNCCD as a key aspect of that is to harness the best available, existing expertise.

MATERIAL AND METHODS

Literature targeted

In order to cover a large diversity of actors in the domains encompassing desertification research, we intended to analyze a large variety of sources. Specific studies focusing on national cases are detailed in other articles in this special issue. In the present study, we sought a more global vision by addressing large international databases. The largest and most easily accessible is the WoS from the ISI, and this is the database we used in our analyses.

Selection of references

In this exploration of publications, we used the WoS online system to query the whole data base of references from 1899 to May 2012. We then progressively narrowed the focus through the following steps.

As a first step: we searched for publications relating to the climatic areas of interest, that is, the *drylands*, and more specifically, papers that focus on the *arid*, *semi-arid*, or *dry subhumid* climatic areas as per the definition used in the UNCCD (these are areas where the aridity index is less than or equal to 0.65, UNEP, 1992). All terms in italics have been used as variables in the first search equation. In the WoS, a topic is a term found either in the title, the keywords, or in the abstract. The search equation used became the following:

*Topic = (dry*land* or arid or semi*arid or subhumid)*

The first query yielded 41 806 references from all around the globe. Even if some of the data mining techniques used at a later stage can theoretically process such a large corpus, the processing time and above all, the display and interpretation of the results would be too demanding for the type of initial analysis undertaken here. For a first data analysis exercise, it appeared necessary to address a smaller data set. We have chosen to be more focused on publications strictly related to key UNCCD issues and its core business of tackling desertification.

Thus, as a second step, we next decided to further narrow down the corpus of references to be analyzed by selecting only references using the term 'desertification' as a topic. The search equation became:

*Topic = (dry*land* or arid or semi*arid or subhumid) and Topic = (desertification)*

The number of references obtained was 1144, which is far more manageable. This equation strictly selects papers in the context of drylands. It eliminates all papers with the topic 'desertification' in other contexts and sometimes unrelated to environmental issues (such as 'medical desertification').

This set of references forms the corpus, which we analyzed in the next two stages, first with the simple tools available online using monocriteria data analysis, and then with the multidimensional analysis.

Monocriteria data analysis

Different variables can be directly retrieved online out of the subset selected within the WoS. In this first part of the analysis, we used simple descriptive statistics such as total number of references and averages per specific criteria. The most informative indicators for such analysis were the following: the number of references per author; the number of references per year; the countries involved in research, that is, the affiliation of authors and the place where research was carried out; and finally, the frequency of keywords.

Multidimensional analysis

The WoS offers the possibility of exporting selected references with their entire description fields, this has been an additional reason for selecting this database. The multidimensional analysis was performed on the data set extracted from the WoS by using the same search equation as in part one. We obtained a file of 1144 records described by variables, the ones used in the processing were name and full first name, publication title, name of the journal, authors' keywords, WoS keywords, abstract, address, number of references, year of publication, volume, number, first page, last page, WoS discipline, and WoS category. This whole set of records described by these variables form what we have called the 'corpus' of references, which were then subjected to our present analyses.

To go beyond the first simple analyses, multidimensional techniques were required. Some co-citation analyses are possible online, but to explore a larger array of these techniques, the use of specific software is necessary.

Multidimensional analyses primarily produce large lists of results, becoming difficult to interpret when they are too dense. In this context, their display as graphs, networks, and maps are powerful techniques for visualization, thus, more easily understandable by users not specialized in scientometrics.

The software we selected to appropriately display our findings is called TETRALOGIE, a trademark of Toulouse Institute of Computer Science Research. This software combines data mining tools and visualization modes interactively, allowing the user to explore the data and refine the way information is displayed at each step, in order to test hypotheses and to enhance the analysis (Mothe *et al.*, 2006).

More specifically, to further explore our data set, we mobilized text mining techniques to apply them to the whole corpus of information through an information processing platform (El Haddadi *et al.*, 2012). In a classical bibliometric approach, the list of parameters analyzed is essentially composed of authors' names, date of publication and keywords. In the present case, all information gathered from the WoS was subjected to the analysis, dealing with two types of information: formal, such as author names, and informal such as the abstract.

In applying these techniques to our corpus, we have dealt with different types of fields, which can be distinguished as (Dousset, 2003):

- Monovalued: having only one possible value, that is, year of publication, the simplest ideal case;
- Multivalued: having multiple values such as the list of authors;
- Diversified: values mixing different things, such as the journal name + volume number + pages.

In order to avoid complex reformatting by distributing each parameter in a separate monovalue field, which is the usual technique for disambiguation, the native format has been kept. To allow this, the format description allows the use of metadata before launching the actual processing. A format descriptor carefully defines the corresponding rules between the relevant fields and the second-level metadata. The data mining process uses multidimensional analyses that involve, for example, classification, clustering, or detection of dependencies.

Among the various types of possible analysis, we selected three different ones showing remarkable features of the scientific community represented in our selected corpus: the network of authors; the interactions between countries; and the disciplines in the context of keywords 'land' and 'soils'. These were selected in order to enable us to achieve the three different objectives outlined earlier.

The network of authors, for example, is represented in a graph G characterized by two sets: a set $V = \{v_1, v_2, \ldots, v_n\}$ whose elements are called nodes and a set $E = \{e_1, e_2, \ldots, e_m\}$, derived from a set $\rho_2(V)$ parts of V, whose elements are called arcs.

We note $G = (V, E)$. G is an undirected graph (there is no distinction between (u, v) and (v, u) for u and v in V) and simple (no loops (v, v) into E and there exists at most one link between two vertices).

Each node is represented by a circle where the size is related to the value of the metric m_i, such as m is the number of occurrence in data collection. From an ergonomic point, the diameter of the circle $D(x_i)$ is:

$$D(x_i) = \sqrt{\mu_i}$$

where μ_i is a normalization of metric values.

Thus, $D(x_i)$ cannot exceed 1 and allows an ergonomic visualization of the network. To improve the graphical representation and obtain a planar display (minimizing the number of intersected arcs), we rely on the analogy 'arc = placement'. The system produces forces between the nodes, which naturally leads to displacement.

In a first step, we propose a general algorithm based on force directed placement (El Haddadi *et al.*, 2011) allowing a better rendering for graphic representation, when the attraction between two nodes u and v is defined (as/by):

$$fa(u, v) = \frac{\beta \text{ x } d_{uv}^{\alpha_a}}{K}$$

β is a constant. d_{uv} is the Euclidean distance between u and v while α_a is used to increase/decrease the attraction.

The K factor is calculated in terms of the area of design window and the number of nodes in the graph. For this, L is the length of the window, l the width, and N is the number of the visible nodes in the graph.

$$K = \sqrt{\frac{L \text{ x } l}{N}}$$

If the nodes u and v are not connected by an arc then f_a $(u, v) = 0$.The repulsion between two nodes u and v is defined (as/by):

$$fr(u, v) = \frac{a_r \text{ x } \mathrm{K}^2}{d_{uv}^{c}}$$

where α_r is the value of the slider, to interact on the repulsion$c$ is a constant.

The placement algorithm is based on the application of the repulsion between all nodes. In a second step, all attractions are taken into account, for any pair of nodes connected.

```
For each node u {if u is visible
            then {
                 Calculating distance d(u,v);
                 For each node v {
                   fr(u,v, d(u,v));
                   if there is an arc between u and v{
                   fa(u, v);
                   }
                 }}}
For each node u {
    if (u is not a mark)
            Moving nodes;
            }
/* *Verification of no-over lapping nodes by comparing
position**/
For each node u{
For each node v{
            if(xu,yu) == (xv, xy)
            then change position of v.
            }}
```

In this algorithm, the parameters were studied to obtain relevant results:

thus, to calculate the *attraction,*

- β is a constant, initialized to 2;
- $d\,^{e}_{\mathrm{uv}}$ is the distance between u and v, where α_a corresponds to the value of the slider can interact on the ride.

To calculate the *repulsion*,

- α_r is the value of the slider, to interact on the repulsion;
- c is a constant, initialized to 1.5

RESULTS AND DISCUSSION

Monocriteria data analysis

The first obvious statistical criterion uses the authors' names to compute the number of papers per author. As an example, Figure 1 presents the 'top ten' authors, ranked by the total number of times their name appears in the 'authors' field of the database.

Although this is interesting for individuals, it gives limited information on the structure of the scientific community represented by the corpus of the analyzed references. One of the most accessible parameters easily computed is the total number of references per year (Figure 2). Contrary to a rather widespread feeling that desertification had gained attention in the period leading up to the negotiation of the UNCCD in the 1990s, but that it is now less studied, Figure 2 clearly shows a recent sharp increase in the annual number of publications.

To further characterize the trend over time depicted in Figure 2, we compared the average number of papers in our data set with the estimated global number of publications, all topics considered (global data from Jinha 2010). As a per year analysis is less pertinent, we roughly divided the period into three distinct groups of years and computed the annual average number of papers in each period (Figure 3).

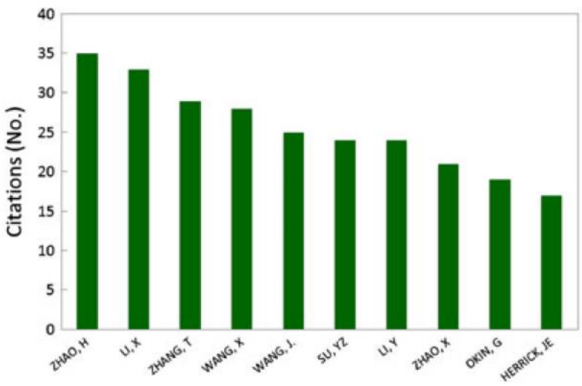

Figure 1. Simple ranking: 10 first authors by the number of citation (1976–2012).

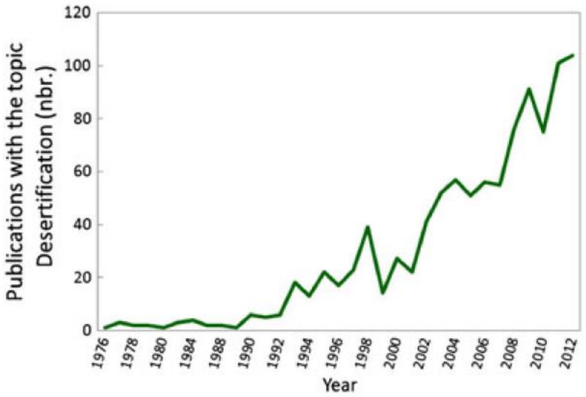

Figure 2. Evolution of the yearly number of publications referenced with topic 'desertification'.

The topic desertification started to emerge very slowly in referenced papers in the late 1970s, then data suggest it received a serious impulse after the first Rio summit and the implementation of the UNCCD and continued to grow in the third period, showing an increase by 25 times from the last period, compared with an average global increase by 126. In other words, the number of references in our corpus grew two times faster during this period than the global corpus, demonstrating the increasing interest in the desertification topic.

For the analysis in terms of countries involved, two aspects have been considered: (a) the countries of the authors' institutions retrieved from the authors' affiliations and (b) the country cited in the title, keyword, or abstract, which is likely (but not guaranteed) to be the country where the research has been carried out. As seen in

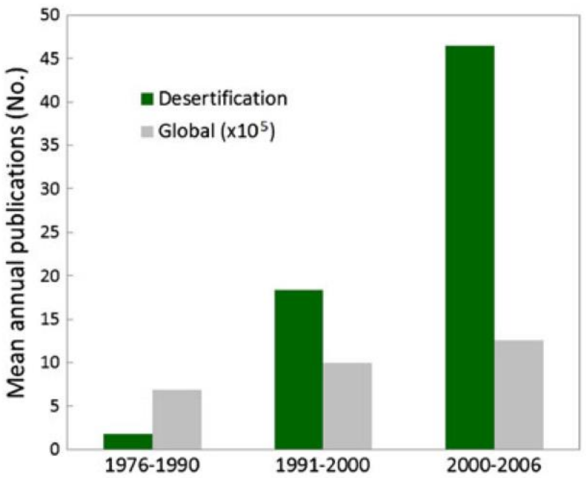

Figure 3. Evolution of the average number of publications per year referenced with topic 'desertification' compared with the global number in three main periods.

Figure 4, the results show differences indicating some researchers are obviously working in countries different from their affiliation.

Strikingly, in both cases, China is clearly ranked first. Excessive exploitation of resources and further large scale soil and water conservation measures have been widely described and published in the last years (Zhao *et al.*, 2013). This prominence is depicted in Table I, showing the results of a simple online query in the WoS for the period 1976–2012. Starting from a very low initial score, the topic 'China' is found in 2012 in one third of all references with topic 'desertification'.

Finally, during the monocriteria analysis phase, we looked at the frequency of keywords. Figure 5 shows that unsurprisingly, the two main keywords cited are 'land' and 'soil', followed by other rather obvious ones. For instance, remote sensing is ranked fifth most cited, showing the importance of this technique in desertification studies, whereas other expected keywords do not appear. The terms 'management' or 'development' for example are essential to land degradation but do not have a high occurrence in the studied corpus of references.

In conclusion, the general results obtained in the first phase of the analyses directly from the WoS have already provided new hints on the research carried out on desertification. However, the monocriteria analyses do not allow insight into the structure of the scientific community involved in this research. This limitation motivated the second part of our analyses and helps us to address some of the remainder of our research objectives.

Multidimensional analysis. Network of authors

The relative productivity of the different authors working on desertification has been addressed in the first phase, but what is more interesting is how they are linked when authors publish together. In Figure 6, distances computed with the graphical method described in the previous section represent the degree of co-authorship among prominent authors. Authors' names appear here just for the sake of illustration, they are abbreviated and locally piled up, this is not meant to represent a ranking among them, but only shows structures appearing in this group

Interestingly, some authors are obviously pivots forming the center of groups or clusters (in bigger red dots in the figure). The main clusters can then be identified and represented individually around the 'pivot authors'. Links between clusters show the role those authors play in establishing bridges within the community.

Multidimensional analysis. Interactions between countries

Figure 4 has already evidenced that the country subjected to the research activity on desertification is not necessarily the country of affiliation of the authors. A dedicated multidimensional analysis allowed us to better decipher among the main two ways a given country is cited in references.

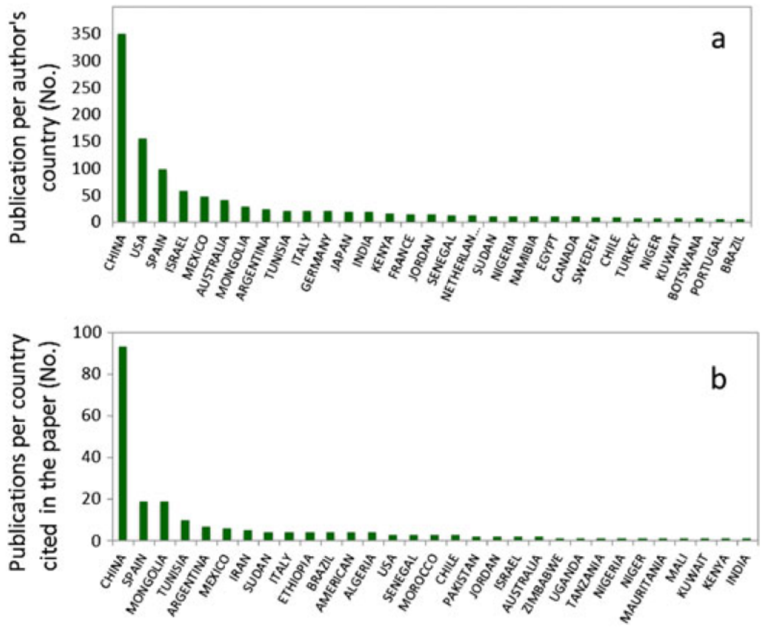

Figure 4. Number of publications per country (a) country of author's affiliation; (b) country cited in the title, keyword or abstract).

Presenting the results of this part in a synthetic way, Figure 7 shows in blue dots and capital letters, countries where the research takes place, whereas names in red and small letters correspond to countries of authors' affiliations. It gives general information about the country of origin of a researcher and the target country or region of research on desertification. Not surprisingly, distinct pairs appear, corresponding to the simple situation where the country is doing research 'on itself' as we see for Brazil, Chile, Iran, Israel, Pakistan, or Sudan. Some countries do not show identified countries of application (isolated dots). This occurs when number of citations are lower than the threshold for visualization on the graph.

More interestingly, some strong connections emerge, such as USA working in China, Mexico, Mongolia, and in the USA. Conversely, China predominantly works in its own territory and in Mongolia, but is cited by authors from Canada, Germany, Japan, Mongolia (and the USA, as mentioned). Surprisingly, Spanish scientists work essentially in Spain, but scientists from Australia, Belgium, and Canada refer to Spain in their work description.

Table I. Number of references in the Web of Science with topic 'desertification': The growing part of China.

	'Desertification'	'Desertification' and 'China'	
Period	Total	No.	%
1976–1990	204	3	1.5
1991–2000	569	40	7.0
2001–2006	711	201	28.3
2007–2012	1243	410	33.0

In the 1990s, the strongest research capacities in the field of desertification could be found among authors from developed countries and among experts living in areas that were not affected by desertification (Seely & Wöhl, 2004). In recent years, this seems to have changed as new countries suffering desertification have increased their presence in the corpus of research of the WoS. Figure 4b shows the ranking among the surveyed countries. China, Spain, Mongolia, Tunisia, and Argentina lead the ranking list. According to the Royal Society Report published in 2011 (RS Policy Report, 2011), the USA is leading the world in global research, as it produces 20% of the world's authorship of research papers. This report also stated that China has increased its publications, being at that date the second highest producer of research output in the world, and foreseen as the leader by

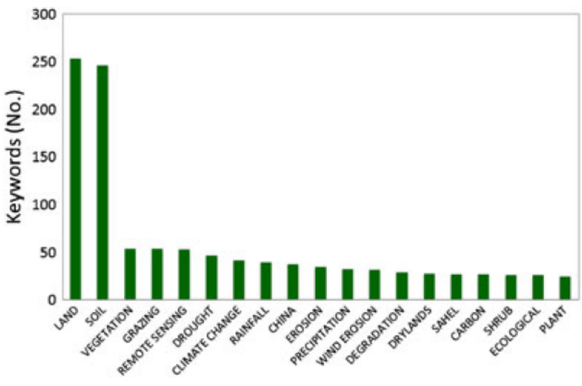

Figure 5. Occurrences of main keywords.

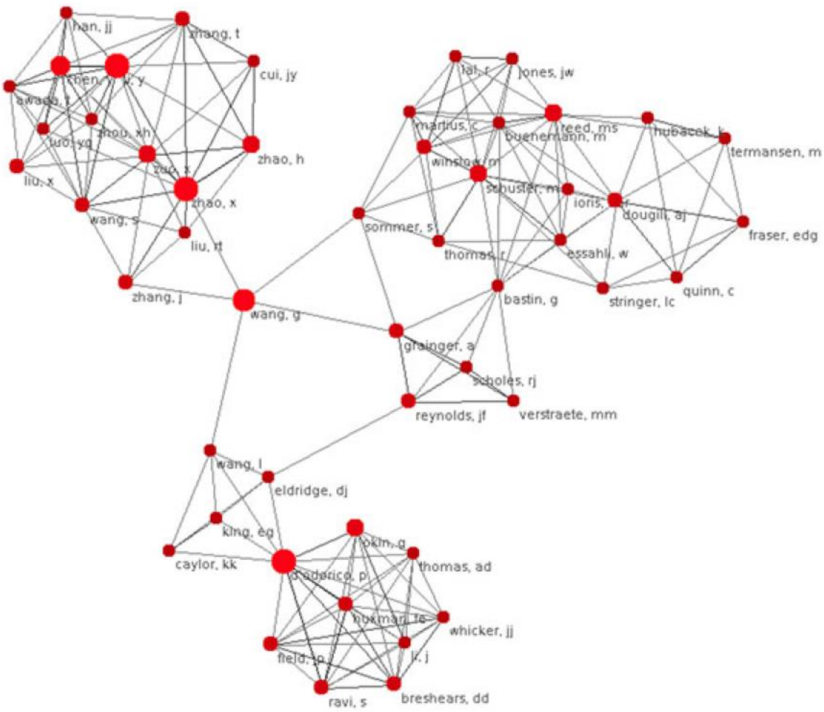

Figure 6. Examples of distances computed between authors. Clusters show group of authors publishing often together, in between them 'pivot' authors are establishing bridges. This figure is available in color online at wileyonlinelibrary.com/journal/ldr

2013. In this study, China is currently leading the research production on desertification, both as country of author's affiliation (Figure 4a) and as country cited in the title, keyword, or abstract (Figure 4b).

This striking result seems due to the large number of new Chinese scientific journals published in English to overcome the language barrier. And indeed, other countries are dealing with the difficulty of publishing their results in

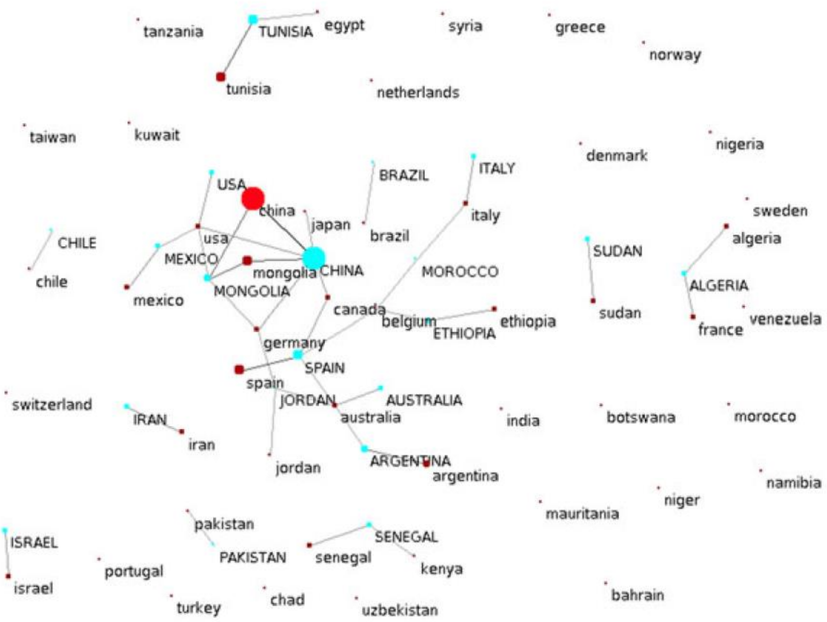

Figure 7. Relationships between affiliation and topic for variable 'country' (in blue dots and capital letters: countries cited in 'topic', in red dots, and small letters: countries of authors affiliations; size of dot is related to the number of publications). This figure is available in color online at wileyonlinelibrary.com/journal/ldr

their national language. The results are shared between English language journals and their own language publications. As an example, we tried to involve the Observatoire du Sahara et du Sahel (OSS), whose mandate deals with the circum-saharan environment. However, their database of publications, a large part being published in French, could not be made compatible with the one we extracted from the WoS (our 'corpus'). Therefore, it could not be incorporated in our analyses. Many other African institutions engaged in desertification studies might also have relevant references. However, from the experience cited, we did not further explore the possibility.

There are more than 13 000 Spanish language journals and more than 5000 Portuguese language journals produced in the 30 countries of Latin America (Cetto *et al.*, 2010); 47.37% of them being devoted to scientific research. Regarding desertification research, two Spanish language countries lead the ranking: Spain and Argentina, both having more than 50% of their territory under dryland climatic conditions and suffering a significant risk of desertification according to their corresponding National Action Plans to combat desertification.

Tunisia is considered an emerging country in desertification-related publications. The country has shown one of the fastest rates of growth in scientific publication output (Royal Society Policy Report, 2011) related to a substantial restructuring of its national Research and Development system. The fight against desertification is one of the national research priorities (Madikizela, 2005).

Spanish and French languages also appear in the WoS database, although they are negligible compared with English. Li *et al.* (2011) used bibliometric methods to analyze the latest advances in climate change research in WoS and found 0.62% of articles were published in French, 0·17% were in Spanish and only 0·17% of papers were in Chinese.

Books and non-English research publications are not included because of administrative or linguistic reasons. They may have a high scientific quality, nevertheless, this knowledge is obscured by WoS (Stoops, 2009). Even if the view presented in Figure 4 is necessarily incomplete and suffers the bias inherent to this study (see conclusion), it depicts in a synthetic way, strong trends in current collaborations, and may trigger ideas for new ones.

Multidimensional analysis. Disciplines in the context of keywords 'land' and 'soils'

The power of the multicriteria analysis also appears when analyzing the distribution of 'disciplines' (as assigned by the WoS) among the references. Different ways to compute and display their links have been tested. We have been particularly interested in analyzing whether the two main keywords 'land' and 'soil' are interchangeable or if differences can be found between papers citing one or the other as keyword.

Figure 8 summarizes some of the findings. Not surprisingly, both keywords have many links to disciplines in common; however, some specific features appear:

- The keyword 'land' shows additional connections with sociology, anthropology, economics, public administration, business, and even mathematics;
- The keyword 'soil' has unique links with applied microbiology, biotechnology, optics, and even astronomy.

These two simple observations would require further in-depth analysis to refine the differences observed. However,

Figure 8. Disciplines connected with 'land' and 'soil' topics, respectively (dot size expresses occurrences). This figure is available in color online at wileyonlinelibrary.com/journal/ldr

a clear trend can be observed: 'land' is associated more with disciplines of the domain of social sciences, whereas 'soil' has more connections with natural or physical science usually known as 'hard sciences'.

However, these results do not allow to estimate how many of those publications are actually offering results applicable to the combat against desertification. The immediate or future applicability of these hard sciences or pure science in environmental issues was addressed by Seely & Wöhl (2004). They analyzed research papers published in five peer-reviewed journals for the period 1997–2001. Only 6%, on average of the 4503 publications were considered as papers providing results that could be applied. Undoubtedly, researchers are skilled in their specific areas of research, but most of them have no interest in or possibility to take their research further. Results, published in peer-reviewed journals are mainly used for recognition in the scientific community. Consistent application of integrated scientific knowledge would be a priority for future implementation of dryland development policy (Bisaro *et al.*, 2014).

CONCLUSION

In Europe, the major publisher on 'desertification' is Spain, whereas at the global level, China appears both as an actor of research on desertification but also as a territory for its research application. As a very large proportion of China can be considered as drylands, this finding shows the significant involvement of Chinese research activities in those environments. The strong increase in the number of publications can also be linked to the diversification of journals and authors during recent years, particularly those from China, who are increasingly engaged in publishing in English.

Compared with simple statistics outlined in the first part of this paper, the second part of the work demonstrates the usefulness of the multidimensional analysis based on text mining. The few examples presented here show the diversity of the scientific community by evidencing clusters of authors. They also show the diversity in terms of 'who is working where' and any cooperation links in space and time. Finally, the analyses also indicate that research on 'soil' and/or 'land' involves a set of similar disciplines but also that each topic has specific links with certain disciplines. Even if these first trends would deserve further in-depth analyses, it can already be concluded that the scientific communities addressing 'land' or 'soil' issues are not identical. This has practical consequences when designing expert panels that should provide policy relevant advice on either 'land' or 'soil' and is an important consideration for the UNCCD.

However, before drawing strong conclusions, it must be reminded that the 'corpus' we have analyzed is only a small subset extracted from the WoS. This database is known to have a weaker indexation of articles in the field of humanities and social sciences (Hicks, 2004). Moreover, it collects only bibliographic data from referenced journals published in English. As a result, there is a serious bias in terms of representativeness of the (broad/global) scientific community in terms of disciplines and from regions of the world speaking other languages such as French or Spanish, and using it as a support for science.

Scientists and experts from francophone Africa (North and Western) publish a majority of their work in French, even though most of those involved in international projects are now also publishing in English in higher ranked journals. As these regions are encountering severe desertification, their work should be taken into account in future bibliometric analyses. Similarly, a significant part of Latin America and the Caribbean is affected by desertification and produces a large set of research results; however, many of them remain invisible in the WoS.

In further studies of this type, it will be necessary to undertake a formal meta-analysis of the larger array of reference sources and attempt to describe each of their fields in a way to make them potentially part of a wider analysis. Combining databases with different structures will nevertheless limit the analysis to the variables in common; for instance, there is usually no description of the 'disciplines'.

As a final conclusion, in the context of the discussions on scientific background for dealing with desertification at the international level, in particular through the UNCCD, the bibliometric approach as tested in this first application to this topic shows its potential in evidencing: (a) the main actors, (b) the existing links between research teams from different countries and by contrast the lacking ones, (c) countries doing research compared with those subjected to it (and the combination of the two) and (d) the width of the 'cloud' of disciplines involved in connection with 'land' and/or 'soil' studies. We argue that any team of experts having to provide scientific guidance on desertification at the international level will benefit from this type of analysis. Indeed, it is vital in order to better understand the 'clusters' involved and their relationships, and to identify potential gaps.

Further work in this domain will have to consider enlarging the data set outside the strict 'desertification' labeled studies and to reach a real international dimension, it will have to include publications in other main scientific languages.

ACKNOWLEDGEMENTS

We thank DesertNet International (http://www.desertnet-international.org/) for providing us with a platform for scientific discussions and dissemination of knowledge.

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06

How is desertification research addressed in Spain? Land versus soil approaches

LAND DEGRADATION & DEVELOPMENT
Land Degrad. Develop. **26**: 423–432 (2015)
Published online 10 March 2015 in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/ldr.2344

HOW IS DESERTIFICATION RESEARCH ADDRESSED IN SPAIN? LAND VERSUS SOIL APPROACHES

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Received: 7 November 2014; Accepted: 8 November 2014

ABSTRACT

This study intends to understand how desertification research is organised in Spain. We assume that a strong communication between scientific knowledge and stakeholders is needed to slow down and reverse the impacts of land degradation on drylands. With this purpose, we conducted an in-depth study at a national level in Spain. The work focused on a sample of published references on desertification in scientific journals indexed in the Web of Science (WoS). The keywords were related to 'desertification', 'drylands', 'land', 'soil', 'development' and 'Spain'. Multivariate analysis, bibliometric techniques and network analysis were used in order to (i) identify research categories and their temporal evolution throughout the period under consideration (1989–2012), (ii) determine if there were different approaches amongst different regions affected by desertification in Spain, (iii) establish the relationships between research categories, (iv) characterise types of co-authorship and (v) map out the Spanish network on the science of desertification. Erosion-soil degradation and soil analysis are the most important research categories, whereas climatic issues are subsidiary and quite isolated from the rest of topics. Very few articles consider 'desertification' as the main theme. Socio-economic issues have scant links with the core of biophysical science. The Spanish network on the science of desertification shows a low density. Moreover, the relationships between universities/research centres with other stakeholders are marginal. This is not the best scenario for transforming scientific knowledge into practical tools for policy makers and land users. Knowledge transfer should be a priority for national desertification programmes. Copyright © 2014 John Wiley & Sons, Ltd.

KEY WORDS: bibliometric; social network analysis; multidisciplinarity; drylands; Spain; UNCCD

INTRODUCTION

Following the Rio Summit of 1992, three major international environmental agreements were signed: The United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity and the United Nations Convention to Combat Desertification (UNCCD). The latter has been considered the 'Cinderella' of the group (Grainger *et al.*, 2000) as witnessed by its meagre funding, weak international public awareness and dysfunctional scientific advisory panel.

The successful implementation of the UNCCD has rested on the involvement of different stakeholders (land users, policy makers, scientists, development community and media) (Vogt *et al.*, 2011; De Pina Tavares *et al.*, 2014). All of them are aware of the important relationships between biophysical and socio-economic issues, but the interaction or flow of knowledge between stakeholders remains weak or inexistent (Stringer *et al.*, 2007; Bauer & Stringer, 2009; Grainger, 2009; Thomas *et al.*, 2012). Moreover, research is usually focused on biophysical factors (Seely & Wohl, 2004; Vogt *et al.*, 2011), limiting the research uptake scope.

Analysing the publications in the field of desertification science may shed light on the structure and evolution of this discipline, helping to improve its implementation. To this end, bibliometric and social network analyses are useful tools. Bibliometric analyses have been widely used to test the quality of journals, but they also provide relevant information that check the impact of specific thematic fields, research teams or study regions (Jappe, 2007; Sakata *et al.*, 2013). Social network analyses identify variations in structure across different scientists and theme clusters, and they use these variations to explain differences in outcomes (Prell *et al.*, 2008; Bodin & Crona, 2009; Reed *et al.*, 2009; Crona & Hubacek, 2010). They are based on the relationships between nodes (researchers or publications) so that the position of a node in a network determines the opportunities and constraints for the flow of information. Bibliometric and social network methods can also be used for strategic decision support. In fact, they have been applied in the assessment of scientific trends of climate change (Janssen *et al.*, 2006; Li *et al.*, 2011).

Desertification in Spain is a relevant topic, as it is the European country with the largest area under risk of desertification (Rubio & Recatalá, 2006; Domingues & Fons-Esteve, 2008) and globally the second country in research production on this topic (Escadafal *et al.*, 2015). It is acknowledged that desertification research should be implementation oriented (Reynolds *et al.*, 2011; McDonagh *et al.*, 2014). To this aim, the parties of the Convention have

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National Action Plans (NAPs) acting as policy tools with different levels of success. The Spanish NAP formulates the need to select socio-economic indicators (MAGRAMA, 2008). This approach had precedents in the Land Degradation Assessment in the Mediterranean (LADAMER 2002–2005) and Surveillance System for Assessing and Monitoring of Desertification (DeSurvey 2005–2009) projects. Both tried to bridge the gap between science and policy to detect, prevent and resolve desertification risks. The Spanish NAP recognised the difficulties of transforming scientific knowledge into practical tools for policy makers and land users, but no specific follow-up proposals or funding opportunities are provided.

We propose that desertification research can be approached from two different perspectives: a specialized perspective that is usually rooted on biophysical sciences and can be termed 'soil vision' and an integrated, natural–social sciences perspective (Reynolds *et al*., 2011), which can be termed 'land vision'. We shall employ this dichotomy to describe and analyse the structure of desertification research in Spain.

MATERIALS AND METHODS

Data Collection

We searched for publications in Web of Science (WoS), both from the Science Citation Index and Social Science Index. Spanish research published in international refereed journals started in the late 1980s (Jiménez-Contreras *et al*., 2003; Escribà & Cortiñas, 2013; Purnell & Quevedo-Blasco, 2013). As we wanted to assess the impact of the UNCCD, we selected four sexennial periods, one prior to the signing of the Convention and the following three. Thus, the search period was 1989–2012. The database search equations appear in Table I. The search was carried out in November and December 2012.

We used three main search combinations: desertification, erosion and Spain produced 86 papers; dryland (encompassing the terms dryland, arid, semiarid and subhumid), erosion and Spain yielded 396 publications; and dryland, desertification and Spain resulted in 102 papers. Combined, they represent 584 documents of which 107 were duplicates. Given the focus of our work, we conducted additional searches that combined desertification with other relevant keywords in order to assess the links between desertification and social-oriented and development-oriented research. Some of these combinations were void, underscoring the lack of connection between concepts that should have been interrelated a priori.

Dataset selection was performed after the review of the title, keywords and abstract of each document. Apart from the duplicates, any article that fell out of the subject or regional scope, and those without an author's keyword (our analysis is based on the authors' keywords; hereinto keywords), was also removed. The final database consisted of 342 references, which corresponds to 668 authors and 1166 keywords.

Database Limitations

Web of Science and searching criteria have some limitations that deserve attention. WoS is not the only publication database. The restriction of WoS to peer-reviewed articles may thus be an important drawback. Other databases such as Francis, CAB or CAIRNS have valuable information, compiling biophysical and socio-economic knowledge, including grey literature, books and book chapters. These types of documents are more likely to include socio-economic issues (Hicks, 2004), although their accessibility is limited and their different structures hinder data processing.

Non-English literature is largely excluded in WoS. As mentioned earlier, in the case of Spain, the priority to publish scientific knowledge in international impact journals

Table I. Web of Science search equations and number of articles per search

Search commands using the field topic	No. ref.
desertification AND erosion AND Spain	86
dry*land* OR arid OR semi*arid OR subhumid AND erosion AND Spain	396
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification	102
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND land	64
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND land AND degradation	40
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND land AND land management	19
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND land AND land access	0
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND soil	77
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND soil AND degradation	41
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND soil AND management	18
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND soil AND properties	24
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND soil AND sealing	1
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND development	21
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND development AND economy	0
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND development AND policy	7
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND development AND gender	0
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND development AND food	0
dry*land* OR arid OR semi*arid OR subhumid AND Spain AND desertification AND development AND poverty	0
Total number of references without duplicates	477

(in English) has taken place over the last three decades; hence, any previous research in Spanish would not be present in this study. This information, however, is not negligible and merits further attention. Finally, another factor that is difficult to evaluate is the possibility of missing articles that would be relevant, as they might not match the keywords given in the search equations. In spite of these shortcomings, WoS is considered the world's leading citation database covering multidisciplinary content from the highest impact journals, giving it an important advantage as the search can be easily refined and replicated in other countries or regions. This will facilitate international comparisons and the analysis of different strategies that eventually can be used worldwide.

Database Organisational Criteria

Several fields were selected from the final 342 selected publications to define attributes assigned to articles and/or authors in order to answer the questions posed in the objectives (Table II). These attributes help to assign characteristics related to the period, co-authorship or collaboration, having been used as the data set for our analysis.

Keyword Organisation

The WoS describes each article by several keywords, which usually results in a long and repetitive list of keywords. Therefore, it is advisable to group them in a reduced set of research categories. The 1166 keywords (S1) were grouped into 13 categories after individual revision, discussion and agreement between the authors. Examples of these classifications can be seen in Tables III and IV. These categories were used to identify the main research topics addressed by the authors and the articles. Three categories were removed to avoid redundancy (e.g. 'location') or lack of relevance (e.g. 'project' and 'not defined'), leaving a final set of 10 research categories for our analysis. Each author was assigned to the modal category of the articles in which she or he appeared. Each article was assigned to as many categories as relevant (see examples in Table IV).

Data Analysis

The database was analysed from two complementary perspectives: one focussed on authors and another on articles. Different data matrices were then produced for each type of analysis. Descriptive statistics were carried out (software SPSS 21) using the 'articles-by-categories' and 'authors-by-categories' matrices. Multivariate analyses were conducted (SPSS 21 and software PC ORD 6) on the 'articles-by-categories' and 'regions-by-categories' matrices. Network analysis permits the representation of the structure of collaboration between authors and the links between research categories in the articles (Zartl *et al*., 2002). It was conducted (UCINET 6·414 and NetDraw 2·123 softwares) using 'author-by-author' (mode I) and 'articles-by-categories' (mode II) matrices.

A Shannon–Wiener diversity index (Spellerberg & Fedor, 2003) that takes into account the relative distribution of

Table II. Summary of basic database fields of the Web of Science and main questions to be addressed

Database field	Description of attributes	Addressed questions
Keywords and abstract	Author's keywords and abstracts were manually checked	What are the most important topics addressed in desertification research in Spain and what are their relationships? How these relationships reflect the possible interactions between environmental and human issues?
Period	Assignment of a period (1989–1994, 1995–2000, 2001–2006 and 2007–2012) considering the reference's publication year	Are there differences in the appeareance of different research categories along the period studied?
Region	Assignment of the region studied in each paper: Aragón Ibérica, Canary, Centre, East, Ebro-Monegros, International, North Mediterranean, Pyrenees, S-SW, SE and Spain, Isolated or Not defined	Are there different approaches amongst different regions? If so, is this related to a prevailed land or soil vision in different regions?
N_authors	Number of authors collaborating in the paper	Is the number of authors/article increasing over time? Is there a relationship between the number of authors/article and the multidisciplinarity of articles?
International team	Difference between international co-authorship and only Spanish authors	Is international co-authorship increasing over time? Is international co-authorship related to multidisciplinarity?
Collaboration between stakeholders	Assignment of the kind of institutions (University-research, Agrarian services, Public administration, Private sector and Civil Society Organization) involved in the reference and collaboration between them	Is there a significant collaboration between scholar institutions and other stakeholders?

Table III. Groups of 13 research categories elaborated with 1166 different author's keywords appearing in the database ranked by the number of times mentioned in the whole database

Categories	No. category mentions	No. keywords per category	Examples of keywords included in the category
Erosion-soil degradation ('eros-sdg')	388	153	Degraded soil, detachment dynamics and gully
Soil analysis ('soil-analysis')	268	195	Carbon sequestration, porosity and soil carbon evaluation
Ecology-vegetation-biodiversity ('eco-veg-bd')	242	180	Afforestation, dominant species and ecotone
Statistics-modelling indicators ('stat-mod')	239	184	Curve number, geostatistics and experimental plots
Land management–land use ('land-use')	223	143	Agricultural land, cover crops and dryland farming
Location *	162	63	Cabo de Gata, Mediterranean Spain and SE Spain
Water ('water')	124	81	Fluvial, drought and hydrology
Desertification–drylands ('des-dryl')	116	31	Dry environments, dryland and arid land
Geology–geomorphology ('geol-geom')	88	69	Badlands, hillslope and karst
Climate ('climate')	52	29	Tertiary, glaciation and semiarid climate
Policy–socio-economic ('poli-soc')	20	18	Stakeholders, participative management and decision-making
N.D.*	19	17	Carbohydrates, roadfill, security and temporal fragmentation
Project*	4	3	EU programmes, EU project Recondes and Socrates
Totals	1945	1166	

*(not used in the analysis, not considered as main categories) For the complete list of keywords in a given category, see S1.

research categories for each sexennial period was calculated (Diversity 2·2 software).

RESULTS

Evolution of Research Categories

Desertification research in Spain has significantly expanded in the past 25 years, having experienced a 14-fold increase from 2·3 articles per year in the pre-UNCCD sexennial 1989–1994 to 31·8 articles per year in 2007–2012. Moreover, Spanish researchers have increasingly participated in international teams: while during the first sexennial, 21% of the articles were co-authored with foreign scientists, the collaboration had increased to 30% in the last sexennial. The Spanish territory itself has been occasionally incorporated in international desertification-related comparisons; 22 articles of our set correspond to this kind of comparisons.

Research results published in this type of journals is by and large conducted in Universities and Research Centres. Collaboration between this kind of institutions and other stakeholders such as rural extension and agriculture agencies, private sectors or NGOs is scant (less than 5% of total articles) and has not increased with time. As expected, because of the vast increase in publications, the number of keywords has expanded (Figure 1A). More interestingly, the increase in keywords varies according to research categories, with 'eros-sdg' (a classic component of soil vision) showing the highest increase while 'poli-soc' (epitomising a land vision) having the lowest growth. The diversity of research has also increased, as can be appreciated using a Shannon–Wiener keyword index that takes into account not only the number but also the relative distribution of research categories. The index increases monotonically, from 2·07 in the first sexennial to 2·17 in the final one. The higher Shannon–Wiener index indicates that research output is more diverse, being distributed more evenly amongst categories. The main change took place just after the signature of UNCCD (Figure 1B).

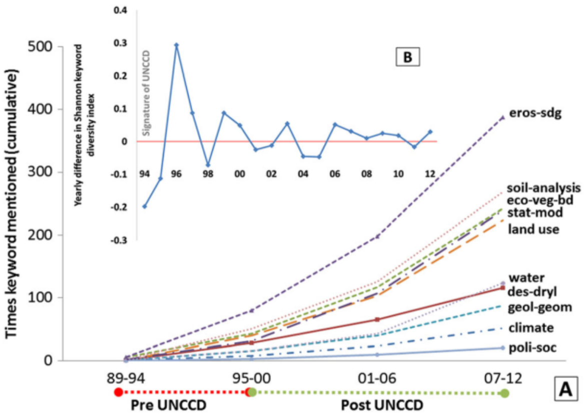

Figure 1. (A) Sexennial cumulative temporal evolution of research categories addressed by keywords mentioned in desertification-related research in Spain. Full categories' names are provided in Table III. (B) 2-year moving average of yearly differences in Shannon–Wiener keyword diversity index. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

Regions and their Research Focus

The Spanish NAP considers that 37% of the territory is subject to medium–high desertification risks. Consequently, desertification-related research concentrates on regions with high risk (Figure 2A). The South east, the driest region in Europe with less than 300 mm yearly rainfall, accounts for 41% of the papers; the four most affected regions (South east, Ebro-Monegros, South-South west and East) represent 74% of the references (Figure 2A). The combination of research categories varies by region, although the four main categories common to most of them are 'eros-sdg', 'soil-analysis', 'land-use' and 'eco-veg-bd' (Figure 2B) over the 23-year period.

Relationships Between Research Categories

The relationships between research categories and how these reflect the possible interactions between environmental and human issues have been performed using multivariate

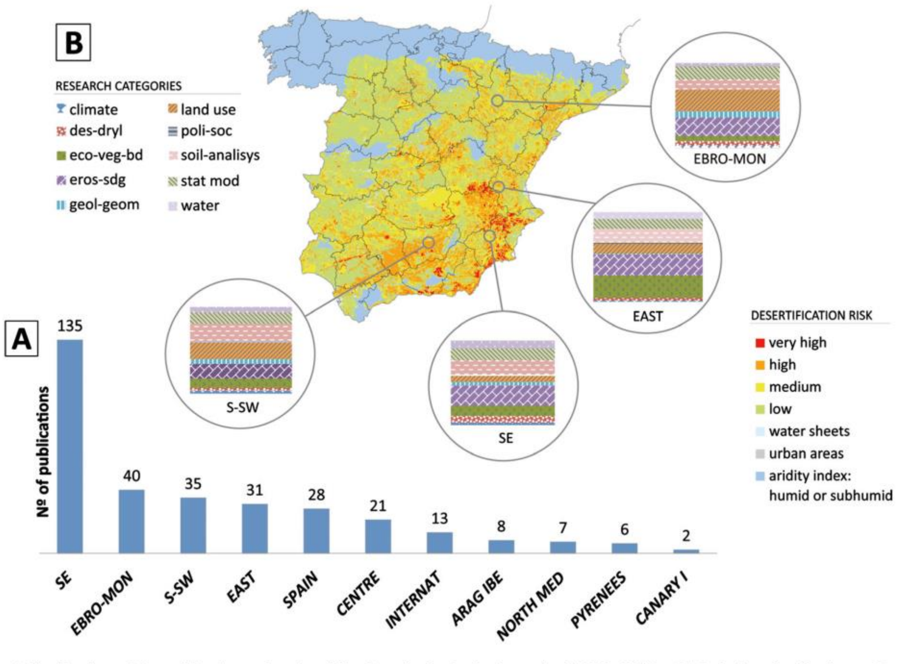

Figure 2. (A) Regional distribution of desertification-related publications in Spain in the period 1989–2012. (B) Relative distribution of desertification research categories in the main desertification-affected regions (South east (SE), Ebro-Monegros, South-south west (S-SW) and East). Map based on National Action Plan, 2008. Ministry of Agriculture, Food and Environment. Map of Desertification Risk in Spain. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

analysis. Figure 3 represents the first two axes of the Principal Component Analysis (PCA) of '342articles-by-10categories' matrix. The first axis (14·5% of variance) separates the classical biophysical categories 'geol-geom' and 'climate' from the more multidisciplinary socio-ecological research of 'land-use' and 'poli-soc'. The second axis (13·3% of variance) differentiates 'soil-analysis', centred on the description of its physico-chemical properties, from 'eros-sdg', which is focused on soil degradation processes.

Figure 4 shows the first two axes of the PCA of the '10regions-by-10categories' matrix. Data were normalised by region to avoid giving more weight to regions where more research has been conducted. The distribution of themes corresponds well with that observed in the previous PCA analysis, with the exception of a closer association between 'soil-analysis' and 'eros-sdg'. The four regions in which most research is concentrated appear in the centre of the graph. Because the data were normalised by region, this indi-

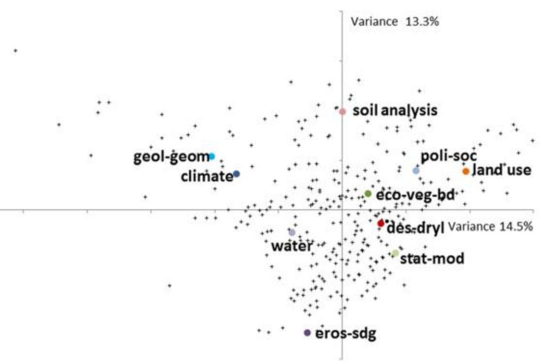

Figure 3. Biplot of PCA of research categories (ten) considering 342 references. (eros-sdg: erosion and soil degradation; eco-veg-bd: ecology, vegetation and biodiversity; stat-mod: statistical programmes, models, geographic information systems and indicators; des-dryl: desertification and drylands; geol-geom: geology and geomorphology; poli-soc: policy and socio-economic issues). This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

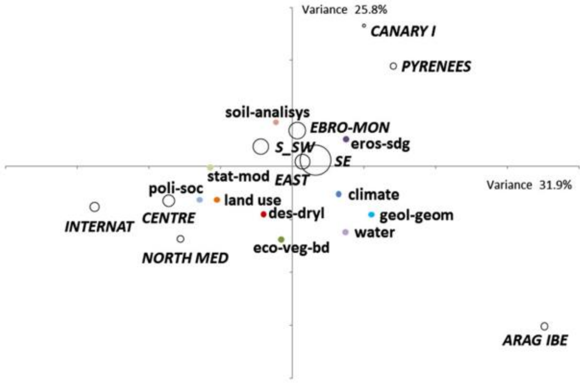

Figure 4. PCA of research categories (ten) and regions (ten). (eros-sdg: erosion and soil degradation; ecoveg-bd: ecology, vegetation and biodiversity; stat-mod: statistical programmes, models and geographic information systems; des-dryl: desertification and drylands; geol-geom: geology and geomorphology; polisoc: policy and socio-economic issues). The size of the bubble represents the number of publications related to that region. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

cates a clear thematic convergence between them. Aragón-Ibérica, Pyrenees and the Canary Islands appear at the extremes of the axes and represent regions with specific problems and with less research conducted on them.

Authorship Characterization

The number of authors in our set of 342 papers varies from 1 to 11, with a mean of 3·7 (±1·7) authors per publication and the modal class being three authors. University/research centre staffs participate in the vast majority of publications (338 papers; 98·8% of total). Other institutions participate marginally: agrarian extension services (7; 2·0%), public administration (6; 1·8%), private sector (5; 1·5%) and civil society organisations (2; 0·6%). This indicates a low level of collaboration; only 16 publications (4·7%) are co-authored between different types of institutions. However, international collaboration is relatively high (92; 26·9%). There has been an increase in international collaboration from one publication in the first sexennial to 52 in the last one that parallels the increase in total number of publications.

There is no statistical difference between the number of authors and the number of research categories (a proxy for multidisciplinarity). However, there are statistically significant differences between national and international co-authorship, the latter tending to have more authors (4·5 vs. 3·3; $p<0{\cdot}001$) and more research categories (3·4 vs. 3·1; $p=0{\cdot}023$). There is no significant difference in the number of authors ($p=0{\cdot}09$) and the number of research categories ($p=0{\cdot}20$) by sexennial period.

The Network of Desertification Research in Spain

Figure 5 shows the authors' network, that is, the links between co-authors of publications and the category to which each author has been ascribed based on a symmetrical, one-way '668authors-by-668authors' matrix. As mentioned, each author was assigned to a dominant research category based on the references of our sample, which limits the variety of research categories that a given author may be working on. Node size represents the author's degree, that is, the measure of the number of ties between authors in the network (S2). It is a low density (1%), decentralised network (centralization index 0·63%) in which only a limited number of authors represent most of the links between research groups.

The four dominant research categories identified in the previous section – 'eros-sdg', 'soil-analysis', 'land-use' and 'eco-veg-bd,' together with 'stat-mod' tools – account for 88% of the links and 74% of the authors. Researchers specialized on 'climate' behave like a clique, a subgroup with strong links between them and little connections with the rest of the network. Less-common researchers are linked to the network mainly through researchers in one of the dominant themes.

The results of the network analysis of 'articles-by-categories' (342 articles and 10 categories matrix mode II) (Figure 6) complement the analysis of authors' network. Whereas in the authors' matrix, each author is assigned to only one research category (the modal category of the papers to which this author has contributed), in the 'articles-by-categories' matrix, a given article can have several research categories based on the classification of the article's keywords. This gives a better representation of the different categories, their relative importance and interconnections. Categories 'eros-sdg' and 'soil-analysis' maintain their key role as the core of desertification research. 'Land-use' and 'poli-soc' categories have a peripheral position in this network, even reducing its relevance with respect to the authors' network. 'Des-dryl' increases its relevance with regard to the authors' network. This is because the keywords included in the 'des-dryl' category tend to be informative enough so as not to need additional keywords, thus reducing its likelihood

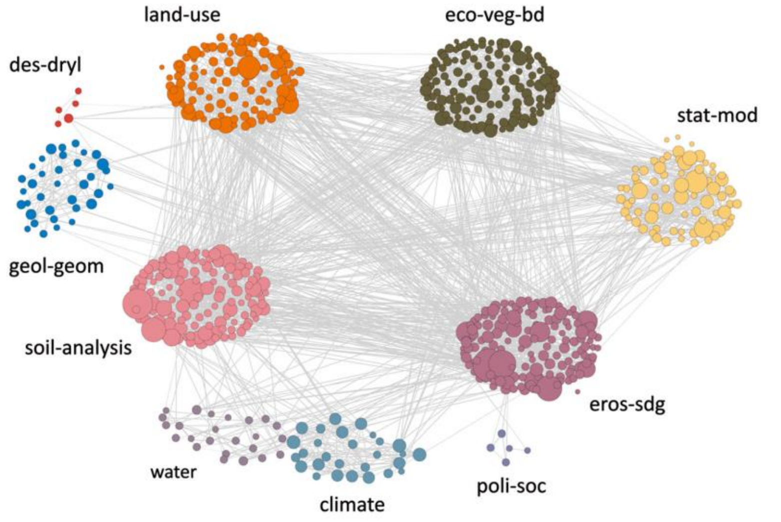

Figure 5. Author's network (668 authors) classified by main author's category (ten research categories). Node size represents author's degree. Five research categories are linked by numerous intercitations: erosion-soil degradation (eros-sdg); soil analysis; statistical programmes, models, geographic information systems and indicators (stat-mod); ecology, vegetation and biodiversity (eco-veg-bd) topics; and land use topics conform this core of main themes. Desertification and drylands (des-dryl) and policy and socio-economic issues (poli-soc) are not frequently found as main themes for authors. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

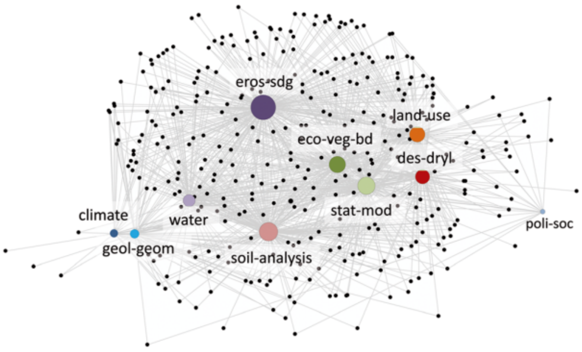

Figure 6. Visualization of research categories relevance in our 342 references sample. The size of nodes represents specific weight of the categories in the sample. (eros-sdg: erosion and soil degradation; eco-veg-db: ecology, vegetation and biodiversity; stat-mod: statistical programmes, models, geographic information systems and indicators; des-dryl: desertification and drylands; geol-geom: geology and geomorphology; poli-soc: policy and socio-economic issues). This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

of being the modal research category for authors. Conversely, the 'climate' category reduces its importance with respect to the authors' network. This is consistent with the aforementioned clique made of few publications with many authors and few connections with other categories.

The degree of the articles (the count of the number of ties to other articles in the network) follows a normal distribution with a modal class of three research categories per article; only seven articles in the sample have a degree greater than 5, these seven articles being enough to link all the ten research categories (Table IV). None of these seven articles has 'poli-soc' as the main category.

The previous inquires provide us with the opportunity to critically answer the questions posed in Table II about the organisation of research on desertification in Spain. Although different factors may have combined to produce the marked increase in research output found in Spain, this is not an isolated case. This increase has been noticed globally as well (Escadafal *et al.*, 2015). The signature of the UNCCD, the adoption of the Thematic Strategy for Soil Protection (Commission of the European Communities, 2006) and the high number of projects funded under the 7th Framework Programme on soil and land issues (European Commission, 2012) seem to have had a major boosting effect.

We tried to determine if the number of authors per article would increase the multidisciplinarity of desertification research and hence the land vision and applicability of knowledge. In this sample, larger authorship is not necessarily related to multidisciplinary research. Nevertheless, when the co-authors were from different nationalities, we found an increase in the diversity of research categories included in the article. The good news is that international collaboration has increased in the last 20 years. Collaboration between various stakeholders is seen as one of the challenges to be achieved to generate the knowledge needed for combating desertification (Yang & Wu, 2010) and to address a long-term oriented implementation of the UNCCD (Stringer, 2008). In spite of it, very few papers were co-authored

Table IV. Seven articles link the ten main themes of desertification research in Spain

Article's references	Author's keywords	Theme categories	Main theme
Le Houérou, 1996	Cactus, Opuntia, arid land, erosion control, land rehabilitation, sustainable development, drought-insurance, water-use efficiency, fodder crops, range management and animal nutrition	'eco-veg-bd', 'eco-veg-bd ', 'des-dryl', 'eros-sdg', 'land-use', 'poli-soc', 'poli-soc', 'water', 'land-use', 'land-use' and 'eco-veg-bd'	'eco-veg-bd'
Bellot *et al.*, 2001	Land use, semiarid, runoff, aquifer recharge, simulation, wildfire and scenarios	'land-use', 'des-dryl', 'eros-sdg', 'water', 'stat-mod', 'eco-veg-bd' and 'stat-mod'	'stat-mod'
Bochet *et al.*, 2009	Vegetation, erosion, eco-geomorphology, water availability, plant traits, soil properties, slope aspect, slope angle, restoration ecology, roots, dispersal and water stress	'eco-veg-bd', 'eros-sdg', 'geol-geom', 'water', 'eco-veg-bd', 'soil-analysis', 'geol-geom', 'geol-geom', 'land-use', 'eco-veg-bd', 'eco-veg-bd' and 'water'	'eco-veg-bd'
García-Fayos & Bochet, 2009	Climate change, interaction models, Mediterranean, plant cover, semiarid, soil erosion, soil fertility, Spain, species richness and water holding capacity	'climate', 'stat-mod', 'location', 'eco-veg-bd', 'des-dryl', 'eros-sdg', 'soil-analysis', 'location', 'eco-veg-bd' and 'water'	'eco-veg-bd'
Cortina *et al.*, 2011	Adaptive management, desertification, ecological restoration, facilitation, participative management, state-and-transition models, steppes and spatial heterogeneity	'land-use', 'des-dryl', 'land-use', 'soil-analysis', 'poli-soc', 'stat-mod', 'eco-veg-bd' and 'eco-veg-bd'	'land-use'
Merino-Martín *et al.*, 2012	Disturbance, drylands, ecohydrological interrelationships, ecohydrology, hillslope, mining and restoration	'stat-mod', 'des-dryl', 'water', 'water', 'geol-geom', 'eros-sdg' and 'land-use'	'water'
Ruiz-Navarro *et al.*, 2012	Erosion, landscape, local topography, semiarid, soil fertility and spatial resolution	'eros-sdg', 'eco-veg-bd', 'geol-geom', 'des-dryl', 'soil-analysis' and 'stat-mod'	'stat-mod'

In case of equal number of theme categories, the main theme was selected after reading the abstract.

by scientists from universities/research centres and other actors belonging to institutions such as regional/state agricultural extension offices or civil society organisations. An implementation-oriented NAP should be based on reinforcing links between different stakeholders (Seely & Wohl, 2004). Our results suggest an ample opportunity to establish links that would address the detected gap.

The Spanish territory shows a puzzling pattern of driving forces leading to land degradation. Climatic and geomorphological conditions coupled with human pressures conform this complex picture (Barbero-Sierra *et al*., 2013). A detailed regional description of these different drivers is not the objective of this study, but the singularities of some regions have emerged in the bibliometric revision and therefore deserve further explanation. Excluding the humid North and North-West of the country, water shortages exacerbated by water demands of high-water crops (Calatrava *et al*., 2010; Grindlay *et al*., 2011), hiperurbanization (Pascual *et al*., 2005), non-sustainable agricultural management of depleted soils (Boellstorff, 2008) and fires (Pérez-Cabello *et al*., 2012) can be considered the most frequent desertification factors. Our results show that these factors coincide with the core themes studied by scientists in all regions. Moreover, each region has specific research focus that relates to local conditions and to the expertise of the research teams that operate in them.

The South-East and East pay particular attention to soil management (García-Orenes *et al*., 2009) and high erosive processes under climate stress (Cerdà *et al*., 2010; García-Ruiz *et al*., 2013). They also touch on policy measures (Calatrava *et al*., 2010; Carreiras *et al*., 2014) and socio-economic factors (Alados *et al*., 2011). The Ebro-Monegros region, located in the middle part of the River Ebro valley in NE Spain, receives around 350 mm of annual rainfall. Gypsiferous and saline soils are especially common in this region. Because of high-speed winds in this area, wind erosion and soil characteristics are usual research topics in this region (Machín & Navas, 1998; Gomes *et al*., 2003). Three regions are isolated in the analysis. The Canary Islands are a diverse group of subtropical islands close to Western Sahara. Desertification processes have been described mainly in Fuerteventura (annual rainfall around 100 mm), related to land cover changes in a soil with salinity and sodicity constraints (Rodríguez *et al*., 2005). Another isolated region in our analysis is the Aragón-Ibérica; this semiarid area (370 mm of mean annual rainfall) surrounds the Iberian Range in Teruel. A Cretaceous desert system marks the regional disappearance of coal-bearing deposits. This is reflected in our sample, which includes geological–geomorphological research of aeolian and dune deposits on the one hand (Lopez-Gutierrez & Negro-Valdecantos, 2000) and the particularities of coal-mine site reclamation on the other (Moreno-de las Heras *et al*., 2009). Finally, the Pyrenees cannot be considered a dry area, as it receives up to 850 mm of annual rainfall. Nevertheless, its shallow soils and high slopes are experiencing a process of population decline, land abandonment and grazing decrease; this entails a set of changes, which peculiarities are studied in the frame of soil erosion (Alatorre & Beguería, 2009).

The thematic convergence found in the most research-productive regions occurs around biophysical categories, confirming the role of natural sciences as foundation and driver of desertification research in Spain. It also indicates the marginal position of integrated, socio-ecological research represented by ‘poli-soc’ and ‘land-use’ categories.

The regional analysis also shows that research on land use and related policy and socio-economic studies tend to be associated to international comparisons and are produced by the two regions (Centre- Madrid, North Mediterranean- Barcelona) that concentrate the largest number of research institutions and universities. This is consistent with the findings of general Spanish bibliometric studies (Escribà & Cortiñas, 2013), pointing to a possible size effect threshold that facilitates multidisciplinarity.

The most important category addressed in this review of desertification research in Spain is soil erosion and soil degradation (‘erosion’ being mentioned 132 times in the keywords field). Erosion processes are strongly related to desertification processes (López Bermúdez, 1990). But it is remarkable that the keyword ‘desertification’ (included in the theme desertification–drylands) is barely used as a descriptor for these articles, appearing only 38 times.

‘Soil analysis’ and ‘Statistics, models and indicators’ can be considered as necessary tools to describe, analyse or represent different conditions. ‘Land-use’ accounts for the group of articles that include the human influence in soil. ‘Ecology, vegetation and biodiversity’ is also an important theme that addresses the relationship between soil and living organisms, especially plants.

Desertification research has been globally affected by emerging issues such as carbon sequestration (Bisaro *et al*., 2014), with strong links with UNFCCC through the relationship between soil organic carbon content and desertification (Lal, 2001). Since 2005, a new thematic trend emerged, and desertification is now considered the result of a long-term failure to balance for and supply of ecosystem services in drylands (Millenium Ecosystem Assessment, 2005; Adeel, 2008). This novel approach is beginning to determine how land degradation knowledge is addressed (Requier-Desjardins *et al*., 2011). The expected links between desertification and erosion, soil carbon, biodiversity or climate change are not visible in this study. In fact, our results show that the strongest clique in our sample is established around the theme ‘Climate change’. The weak connections with articles addressing climate contradict the general trend to link the UNCCD with United Nations Framework Convention on Climate Change (Grainger *et al*., 2000; Cowie *et al*., 2011), suggesting a gap between policy discourses and the concrete way in which desertification research takes place (Grainger, 2009; Winslow *et al*., 2011).

CONCLUSIONS

The use of science as a tool to manage and prevent land degradation has been repeatedly recommended. In spite of it, this study about desertification research in Spain, one of the world's leading countries in scientific publications on dryland degradation, demonstrates (i) the weak links between biophysical and socio-economic issues and (ii) the lack of connections between different stakeholders in scientific publications on desertification. Our work suggests that, in the case of Spain, research is not the main limiting factor to address desertification.

Social sciences propose an approach in line with development that may be helpful for the implementation of science: the use of Research Action Participation. This type of applied science, with the necessary connections with other stakeholders, is typically found in technical reports, and usually not in English. This is not appreciated for the curricula and thus not tied to any motivation or incentive for scientists, who tend to concentrate efforts in Science Citation Index publications, which are in turn ignored by policy makers and land users. The biophysical approach is the core of desertification research in Spain, 'soil erosion and degradation' and 'soil analysis' emerging as the main themes. All these topics are not always identified with desertification and are therefore not visible enough as a keyword or main theme in this corpus of science dealing with dryland degradation.

Socio-economic issues are peripheral in the Spanish community of scientists. The more integrated land vision – represented by the land-use approach and policy and socio-economic issues – is secondary, and so, it remains unreached in science implementation orientation. The approach of this study can be easily replicated in other countries under different circumstances to check whether different kinds of networks are more effective to combat desertification.

ACKNOWLEDGEMENTS

We would like to thank Raúl Peláez and Carolina Batareno for their assistance in data base processing and design.

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Desertification research in Argentina

LAND DEGRADATION & DEVELOPMENT
Land Degrad. Develop. **26**: 433–440 (2015)
Published online in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/ldr.2392

DESERTIFICATION RESEARCH IN ARGENTINA

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Received: 6 April 2015; Accepted: 6 April 2015

ABSTRACT

In Latin America, Argentina is second – behind Brazil – in extent of drylands: 55% of its territory. Research on desertification and dryland degradation has a lengthy tradition, being undertaken even prior to the establishment of the United Nations Convention to Combat Desertification. The paper aims to analyse desertification research in Argentina, the disciplines from which its knowledge arises and the topics receiving greater attention. The work focuses on the results from descriptive, bibliometric and social network analyses of a sample of articles on desertification in scientific journals indexed in Web of Science. A visual representation of citation relationships was created considering keywords such as 'desertification', 'dry*land*', '*arid' and 'development', 'policy' or 'economy' among others, in 'Argentina'. According to this search, the number of papers per year dealing with desertification in Argentina is only 4·3. National knowledge, usually categorized as traditional knowledge, is barely captured by international databases. The challenge for the scientific community is to make traditional knowledge visible and disseminate the findings. Results demonstrate that desertification research in Argentina is in a great proportion related to studies of soil erosion and soil degradation, and only in a minor proportion to socioeconomic issues. However, desertification problems are the outcome of interactions among physical–biological, socioeconomic and political dimensions, and therefore, the science summoned to analyse them must not only be a science centred on isolated themes but also one resulting from interdisciplinary studies and integrated approaches. Copyright © 2015 John Wiley & Sons, Ltd.

KEY WORDS: bibliometrics; desertification research; Argentina; UNCCD; social network analysis

INTRODUCTION

Dryland areas around the world are affected by land degradation (Qadir *et al.*, 2013; Cerdà *et al.*, 2014; Omuto *et al.*, 2014), and Argentina is affected by land degradation processes because of social, economic and biophysical changes (Abraham *et al.*, 2011; Kröpfl *et al.*, 2013; Palacio *et al.*, 2014).

In Latin America, drylands extend from the north of Mexico to the south of Argentina and represent 25% of the land surface area. Seventy-five percent of them have desertification problems (Morales, 2005). In Argentina, drylands represent 55% of the country's land area, and, to varying degrees, all of them have desertification problems (Abraham *et al.*, 2014). The magnitude of the economic losses caused by these processes becomes evident if one considers that Argentina's drylands produce 50% of the agricultural production and 47% of the livestock production and that almost one-third of the country's total population lives in them (SAyDS, 2002).

According to the internationally agreed meaning, desertification is 'land degradation in arid, semiarid and dry subhumid areas, and is primarily due to human activities and to climate variations' (UNCCD/PNUMA, 1995). This notion alludes to degradation processes, understood as processes of productivity loss, anchored in drylands, and resulting from the action of climatic and human factors. Formally, the definition encompasses all lands where climate is classified as dry, ranging from hyper-arid, arid and semiarid to dry sub-humid. This classification is based on values of the aridity index (*AI*), that is, the mean annual relationship between an area's rainfall and its potential evapotranspiration. Thus, hyper-arid regions present an $AI < 0{\cdot}05$, arid regions one between 0·05 and 0·20, semiarid regions one between 0·20 and 0·45, and dry sub-humid regions show an index between 0·45 and 0·70 (UNCCD/PNUMA, 1995).

At global scale, the first concerns related to desertification processes date back to 1977, in particular at the United Nations Conference in Nairobi, where the importance of this scourge is acknowledged, mostly in relation to the drought that affected extensive regions of the Sahel in Africa. It is in 1994, and after verifying that the phenomenon reached global scale, that the International Convention to Combat Desertification [United Nations Convention to Combat Desertification (UNCCD)] is created, a United Nations agency that will concentrate the main discussions around the issue, set the lines of action that should guide the different national states in their combat actions and provide devices for the search for funding sources to help the most affected countries. At present, over 195 countries have ratified the Convention, and in this way, they have become party countries, assuming the commitment to advance in combating desertification processes.

As part of the discussions held within the Convention, now it is recognized that desertification processes are complex environmental problems that combine a natural and social

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cause–effect cycle (Abraham, 2003, 2009; Reynolds *et al*., 2005, 2007; Stringer, 2008). Moreover, it is postulated that desertification and poverty are deeply linked phenomena that cannot be addressed detached from other environmental scourges that have an impact at global level, among which climate change stands out (Stern, 2006). Being a complex problem and one of social/natural linkage, it is imperative that actions to combat desertification should promote dialogue among the scientific community, decision makers, funding agencies and local populations, and, finally, it is necessary that the scientific community accompanies and gets involved in decision-making processes, contributing interdisciplinary and integral studies that value the biophysical, socioeconomic (Reynolds *et al*., 2007) and political dimensions (Torres Guevara, 2000; Stringer *et al*., 2011; Abraham *et al*., 2014) of this process.

The creation of the UNCCD considerably increased the world's interest in drylands, and ever since its origins, the Convention has promoted the adoption of integrated approaches – interdisciplinary and capable of considering the biophysical, socioeconomic, political and institutional dimensions. Despite these recommendations and even minimizing the greater weight assigned in Latin America to the socioeconomic and political dimensions, desertification-related studies coming from the scientific field have taken little notice of the contributions of social sciences and have, over time, given greater predominance to those of the physical–biological sciences (Vogt *et al*., 2011). Along these lines and in particular relation to existing scientific knowledge, it is pointed out that the little available knowledge of drylands is still worrisome, that even scarcer is the knowledge regarding the economic dimensions of desertification and that major difficulties to attain an integrated understanding of the problem still persist. As a result, a recent work carried out at request of the UNCCD indicates that sustainable dryland management remains a pending task (Low, 2013; Poulsen, 2013).

Moreover, several Latin American authors highlight that, under strong economic dependence, the socioeconomic causes of desertification bear more importance than the physical ones, and therefore, both scientific efforts and combat actions should start from acknowledging the primacy of the human, socioeconomic and political dimensions of this process (Torres Guevara, 2000; Ruíz & Febles, 2004; Abraham *et al*., 2014). This is also a trend in the international research community (Izzo *et al*., 2013; Salvati *et al*., 2013; Yan & Cai, 2013; Bisaro *et al*., 2014; Fleskens & Stringer, 2014; Jones *et al*., 2014; Stringer & Harris, 2014).

In Argentina, research on desertification, dryland degradation and drought (DDLD) has a strong development, undertaken before the establishment of the UNCCD. However, until the onset of the 21st century, it was pointed out that existing knowledge failed to capture the characteristics of desertification processes in their whole complexity and that knowledge, overall, was limited to describing degraded natural resources taken isolatedly – resourcist view (Abraham, 2003). This has posed obstacles to the integration of the political, social, economic and natural dimensions into the processes to combat desertification (Matallo, 2005; Pulido & Bocco, 2011).

Given the previous discussion, it is desirable to analyse desertification research in Argentina to detect the light and shadow areas in existing knowledge with a view to planning future endeavours. To proceed in this kind of analytical directions, bibliometric and social network analyses are applied. In last decades, these tools have been increasingly used to support policy decision making (Cross *et al*., 2005; Smith & Marinova, 2005). Bibliometric studies are defined as 'the discipline that measures and analyses the production of science under the form of articles, publications, citations, patents or other more complex derived indicators' (Okubo, 1997 in MINCyT, 2009: 10) and provide knowledge of the characteristics and evolution of research – including that related to desertification – in the country. It is understood that scientific publications are an essential result of the country's scientific activity. Social network analysis also allows identifying relationships and relevance of themes and study regions (Crona & Hubacek, 2010). In this context, research topics are considered nodes, their importance being defined by the number of corresponding keywords mentioned in scientific publications.

Faced with the challenge that scientific knowledge should cooperate in sustainably managing drylands, the goal of this work is to analyse desertification research in Argentina, considering its structure and evolution over time and taking into account the disciplines from which knowledge arises as well as the topics receiving greater attention. Associated to this, it is sought to clarify whether there have been variations over time in the research on desertification and dryland degradation in the country that have brought research close to the comprehensive contents that are internationally required.

MATERIAL AND METHODS

The methodology used has consisted of retrieving articles from Web of Science (WoS) by combining different search commands (Table I). Only seven articles were found when the research commands in WoS were 'dry*land* AND desertification AND Argentina'. Therefore, they were expanded to 'dry*land* OR arid OR semi*arid OR subhumid' in order to capture all the possible denominations around desertification-affected areas. Other keywords related to socioeconomic and policy dimensions such as 'development', 'economy', 'policy', 'gender', 'food' or 'poverty' were included as search commands. This search process yielded papers combining all the concepts pointed out in Table I. The next task consisted of removing unsound references from the database, that is, duplicated articles, papers without author's keywords (our analysis is based on the authors' keywords; herein keywords), articles not corresponding to Argentina or those not related to soil or land degradation. The outcome of this process was a final database containing 72 papers to be analysed referring to 296 different keywords. A number of publications and diversity of themes were analysed along four equivalent 5-year periods – 1993–1997,

Table I. Web of Science search equations and number of articles per search

Search commands using the field topic	No. of ref.
dry*land* AND desertification AND Argentina	7
dry*land* OR arid OR semi*arid OR subhumid AND erosion AND Argentina	81
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification	41
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND land	23
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND land AND degradation	18
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND land AND land management	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND land AND land access	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND soil	24
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND soil AND degradation	11
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND soil AND management	5
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND soil AND properties	5
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND soil AND sealing	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development	8
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development AND economy	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development AND policy	2
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development AND gender	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development AND food	0
dry*land* OR arid OR semi*arid OR subhumid AND Argentina AND desertification AND development AND poverty	0
Total number of retrieved references	218
Final database, excluding unsound references	72

1998–2002, 2003–2007 and 2008–2012 – in order to observe temporal evolution. Diversity of themes was evaluated by Shannon–Wiener's index (Spellerberg & Fedor, 2003) using DIVERSITY 2·2 software.

The articles were then characterized in terms of composition of author groups and main themes addressed. In order to identify these main research themes, the 296 different keywords (all of them included in the Supporting Information) in the 72 articles retrieved from the database were grouped into 12 categories (Table II). Nevertheless, further analyses were conducted only with ten categories to avoid redundancy (e.g. 'location') or lack of relevance (e.g. 'not defined'). In order to establish the ties between themes and articles, a social network analysis was performed. UCINET 6·414 and NETDRAW2·123 were the software programs used. The associations between main themes were identified by principal component analysis considering 72 articles (cases) by ten themes (variables). PC-ORD-6 and SPSS-21 software programs were used.

Table II. Groups of 12 categories elaborated with 296 keywords appearing in the database ranked by the number of times mentioned in the database

Main themes	No. of category mentions	No. of keywords included per category
1. Soil analysis ('soil analysis')	69	62
2. Erosion–soil degradation ('eros-sdg')	57	33
3. Ecology–vegetation–biodiversity ('eco-veg-bd')	52	48
4. Desertification–drylands ('des-dryl')	48	22
5. Land management–land use ('land use')	45	39
6. Statistics–modelling–indicators ('stat-mod')	38	33
7. Location[a]	32	14
8. Policy–socioeconomic ('poli-soc')	14	14
9. Climate ('climate')	10	10
10. Water ('water')	10	8
11. n.d.[a]	8	8
12. Geology–geomorphology ('geol-geom')	5	5
Total	388	296

[a]Not used in the analysis to avoid redundancy (location) or not relevant (n.d.).

RESULTS

Temporal Evolution

According to the searching criteria, since 1993, the number of publications strongly increased over time (Figure 1). Applying Shannon–Wiener's index (Spellerberg & Fedor, 2003) allows

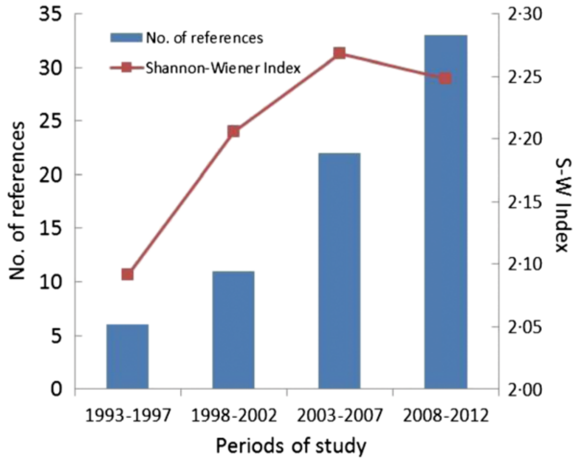

Figure 1. Number of articles published since 1993 to 2012 (left axis) grouped per periods, and the corresponding diversity index (right axis) per period (S-W: Shannon & Wiener).

observing that the diversity of themes shows a significant increase between the first 5-year period – 1993/1997 – (2·09) and the next two 5-year periods – 1998/2002 and 2003–2007 – (2·21 and 2·27, respectively). During the last period, 2008–2012, the diversity of themes decreased (2·25).

Authors' Origin and Eco-regions

Eighty-five percent of the analysed papers have been produced by research teams where Argentinean scientists participate. In 69% of cases, these studies come from groups exclusively composed of Argentinean researchers, whereas 15% are the result of cooperation with foreign institutions. The remaining 16% include studies conducted exclusively by foreign authors, without participation of their Argentinean peers. Preponderant among the latter are studies from the USA (nine of 13 cases), followed by researchers from Europe (Spain, France and Belgium), Latin America (Brazil and Chile) and New Zealand (all of them with one case/publication per country). These data are in keeping with those reported by different national and international studies that analyse the evolution of scientific productivity in Argentina and/or South America. Consistently, with a trend ratified at national level (MINCyT, 2009, 2013), Van Noorden (2014) indicates that when publications are co-authored by South American and foreign authors, the peers from the USA are prevalent.

In turn, the fact that the first authors in domestic research teams are from Buenos Aires (50%) is also in line with the data provided by official Argentinean agencies (MINCyT, 2009). These data show a persistent concentration of researchers and publications around the city and province of Buenos Aires, where the high concentration of resources (MINCyT, 2009, 2013) is acting as a driving force.

The largest proportion of papers is concentrated in the Monte, an eco-region of plains and plateaus, and in the Patagonian steppe (Figure 2). The rest is distributed, with lower values, in the eco-regions of Dry Chaco, Espinal, Monte of Mountains and Depressions and Puna, although not all of these regions are affected by desertification processes, particularly rainforests.

Main Themes

Most of the keywords are related to the biophysical approach: soil analysis, soil erosion and degradation or

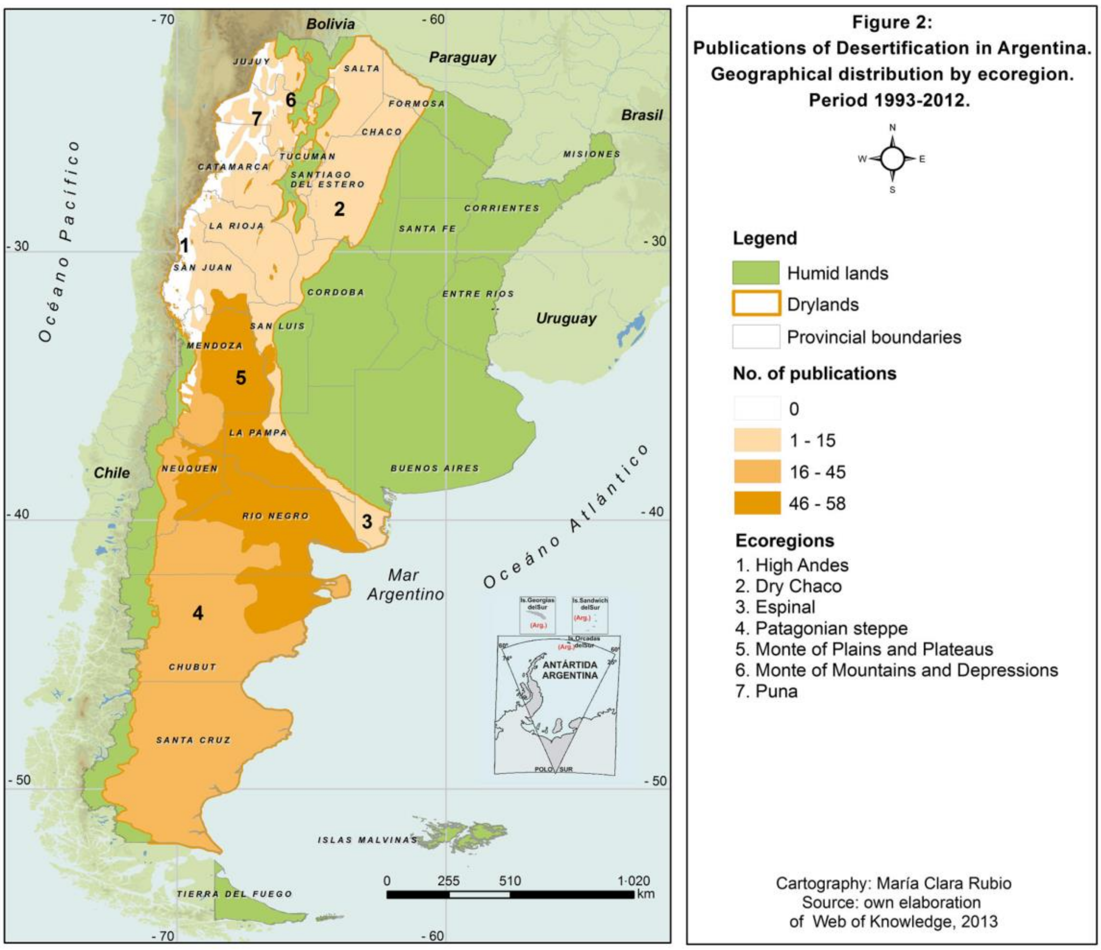

Figure 2. Argentinian Ecoregions.

ecology, vegetation and biodiversity (Table II). The 'desertification and drylands' theme is fourth in rank of importance. Other topics, among them social and political dimensions, are not so much dealt with (14 keywords out of a total of 296).

Network analysis for articles by themes allows representing the different topics, and their relative importance and interconnections in the analysed publications (Figure 3). This importance is valued for their *degree* (the count of the number of ties between articles and themes). On the one hand, the most cited main themes are erosion and soil degradation ('eros-sdg', degree: 36) and desertification and drylands ('des-dryl', 36), followed by 'land use' (31), ecology, vegetation and biodiversity ('eco-veg-bd', 30), and soil analyses ('soil-analys', 29). In turn, policy and socio-economy ('pol-soc-econ', 12), 'climate' (7), 'water' (7), and geology and geomorphology ('geol-geom', 3) appear as the least addressed topics. On the other hand, the diversity of themes in the articles is represented by their corresponding node size, the most diverse articles being found in the Patagonian steppe and Monte and Pampa eco-regions.

In order to identify associations among the main themes, we applied a principal component analysis that captures up to 33% of variance with the first two components (Figure 4). The horizontal axis is related to research on desertification and drylands. The right side of this axis is defined by the main themes regarding the tools used by scientists to manage or represent data such as statistics, models or geographic systems. A tight relationship is found between desertification ('des-dryl') and the tools used to analyse natural processes (statistical methods and models, 'stat-mod'); this can be seen as an attitude of researchers prone to using and mentioning the instruments of science to address desertification problems. The group of themes is completed with variables describing biotic interactions (ecology, vegetation, biodiversity and water) and indicators of erosion and soil degradation. Other variables that are usually used for regional descriptions

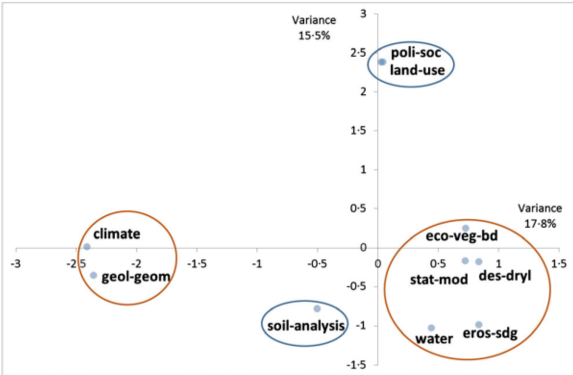

Figure 4. Principal component analysis of main themes.

such as soil characteristics, climate or geomorphology are on the opposite side of the axis. The second principal component (vertical axis) extracts 15·5% of variance and separates the main themes related to land use and policy or socioeconomic issues from those related to soil analysis.

DISCUSSION

Knowledge construction processes cannot be considered detached from the places where they are accomplished. The place or site, in turn, should be understood as a broad category, not merely physical or only indicative of a geographic location, but as spatiality linked to history and to the structural and particular conditions characterizing the contexts in which researchers approach the study of reality (Ramos *et al*., 2004). Part of these contexts is the resources that scientists have at their disposal, the working conditions that they face, the theoretical–methodological proposals available in academic communities and the pre-existing agreements, among other things, linked to what is involved in doing science, what the requirements to be met by good

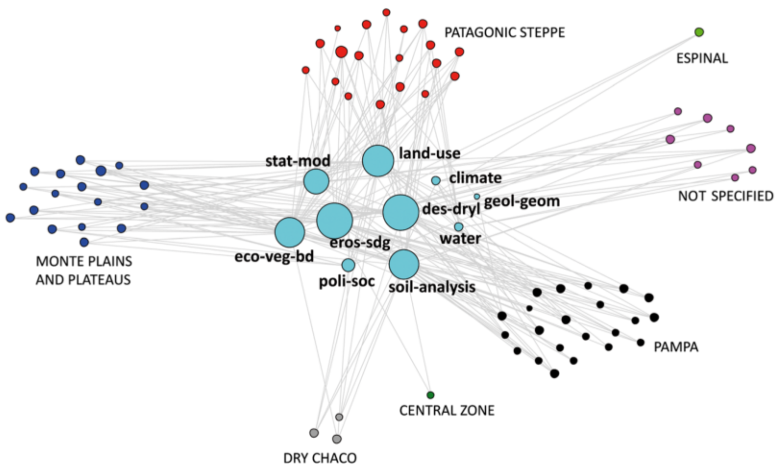

Figure 3. Ties between articles and themes. Articles are grouped by ecoregions. The node size of themes represents their relative importance, i.e. number of mentions as keywords in the articles. The node size of the articles represents its diversity of themes.

quality science are and the criteria that distinguish the publishable from the unpublishable in the different available means of knowledge dissemination. This opens the possibility to dodge the judgment of 'existing knowledge', assuming, plain and simple, that capture of publications in international databases reflects the capacity of scientists. It is possible to note, besides, that productivity-measuring methods are not devoid of their own logics of construction. Quite to the contrary, just as the most internationally visible databases are the result of previous consensus and show a particular selection of what is in existence, beyond them, there is unreported knowledge whose lack of citation does not make it lose its quality as 'knowledge'.

In this sense, it is highly probable that knowledge generated from Argentina in relation to desertification and dryland degradation exceeds that contained in the international databases consulted, a fact that not only makes us think of the context conditions that explain current trends but also invites us to reflect on their quality and validity even when they cannot be reflected in the windows provided by WoS.

The first publications coincide with the establishment of the UNCCD, and, since then, publications exhibit a moderate growth up to the start of the millennium, growing less pressed afterwards. From the thematic viewpoint, the first papers show higher concern for isolated elements of the natural environment (soil, water, vegetation and wildlife), and, over time, a greater presence is observed of studies integrating successive levels of complexity and interaction. In this sense, it is possible to infer that institutionalization of the UNCCD not only produced an increase in scientific production related to desertification but also resulted in consideration of a greater variety of themes, slowly but progressively correcting the resourcist view that prevailed in the past (Abraham, 2003).

For an interval of 19 years, the WoS database reports 82 papers, a figure that yields an average value of desertification-related production in Argentina of 4·3 studies per year, a figure that seems to be low. In spite of this, Argentina has research groups that have increased their efforts to develop the topic and that have delved deep into it over time. Collaborative research has acted in two directions: strengthening its own research groups and enhancing their alliance with foreign researchers. Indeed, the production of studies of desertification in the country is extensive and diverse and has backgrounds that extend back to the late 1970s (Matallo, 2005; Abraham *et al*., 2014).

The fact is that the WoS database does not capture the entirety of studies linked to desertification in Argentina. These studies are available, mostly in Spanish, from Argentina's and Latin America's databases, and they are not included among those offered by WoS. This evidence is consistent with that observed by Van Noorden (2014) who notes that South American investigations fail to attract international citations, among other things, because they are published in journals not indexed in major databases. As a result, some Latin American authors who have made seminal contributions to the understanding of drylands, having published most of their work in Spanish and/or in books (Torres Guevara, 2000; Matallo, 2001; Abraham, 2003, 2006, 2009; Abraham *et al*., 2005; Morales, 2005, to mention just a few), do not appear in the citation database and, consequently, are scarcely cited at international level. Complementarily, there are no studies published in Argentinean journals, and only one appears in a Latin American journal, in this case from Mexico (Marizza *et al*., 2010).

Thus, it is likely that Latin America's and Argentina's contributions are being undervalued in the international sphere, not because they are of little significance or relevance but because they are published, in a great proportion, in non-indexed journals (Van Noorden, 2014). These corroborations are probably denoting a certain narrowness of the major citation databases, which could be attenuated by expanding links with databases that are more sensitive to capturing studies published in other languages, journals and regions.

Considered in their geographical distribution across the national territory and excluding rainforest for natural reasons, prevailing studies on desertification are centralized in three major Argentinean eco-regions facing critical desertification processes (SayDS, 2002): Patagonian steppe (32%), Pampas (31%) and Monte (27%). In all these regions, research efforts regarding DDLD started early because desertification in their territories was an environmental problem of great magnitude, affecting their productivity and social foundations. Moreover, in these regions, there are institutions with experience in the study of drylands that were created before the UNCCD was established (*Instituto Nacional de TecnologíaAgropecuaria*, in 1956; *Centro Nacional Patagónico*, in 1970; *Instituto Argentino de Investigación de Zonas Áridas*, in 1972; and *Centro de Recursos Naturales Renovables de la Zona Semiárida*, in 1980, among others). For the time being, investigations conducted in Chaco and Puna, two eco-regions also seriously affected by desertification, are not listed in WoS, even though, as in the previous cases, they had scientific capacities on DDLD before the creation of the UNCCD (Abraham *et al*., 2011).

The analysis of the reported papers also shows great predominance of interests linked to the biophysical dimensions of desertification and a clearly peripheral position with respect to interests related to its human, political, economic, social and cultural dimensions. This is revealed in the fact that none of the 72 studies incorporates gender, food or poverty dimensions and that only one of them includes the notion of economy and two include the notion of policy. The orientation taken by the analysed studies justifies the trends indicated by the UNCCD recommending the integration of visions reflecting the inherent complexity of desertification into studies of the topic (Akhtar-Schuster *et al*., 2010; Low, 2013; Poulsen, 2013).

An analysis of keywords in these papers corroborates the foregoing considerations. These studies are in a high proportion related to soil, erosion and soil degradation. Further research should enable establishing whether these studies take into account the category 'land use' in a broad or narrow sense; that is, as a driving force that could be an explanatory factor of the orientation taken by agricultural and livestock rearing practices at a given time or as the soil's capacity to support agriculture and livestock activities.

Finally, it is necessary to point out that outside of science, a sustainable management of drylands depends on the addition of another knowledge, which is not traditionally assimilated into this field but which, however, is a key factor in facing the challenge to think/act in the context of society/nature relationships. Previous analyses associated to scientific knowledge are indicative of how science has thought/analysed a topic, but are not supposed to assume that they are the 'exclusive or right' way to think/approach the issue/problem. So, to the challenge of making visible the production of scientific knowledge not captured by international databases should be added the challenge of acknowledging and visualizing the wide array of knowledge existing in the region, many times categorized as traditional, which tells us of the society/nature linkage and which might make substantial contributions to sustainable management processes.

Desertification should be a science within the reach of the affected dimensions – physical–biological, socioeconomic and political – and decision makers and should find a crucial point that could translate into the design of more assertive sustainable land management actions. Overall, the analysed papers are hardly available to the affected communities and decision makers in Argentina, not only because they have been published in a foreign language but also because they fail to bring together dimensions of analysis that are integrated in the real world. Available studies of soil, water, wildlife and even those considering soil–productivity–vegetation relations are of undoubted scientific quality and contribute to the understanding of desertification processes. But they fail to overcome, at least for the time being, the barriers imposed by disciplinary boundaries, let alone advance in an integrated understanding of desertification processes. In this sense, Argentina does not escape the global trend warned at the UNCCD and in Argentina's NAP because although the country is working on consolidating a solid and competitive System of Science and Technology, it still faces the challenge to achieve better channels of linkage.

CONCLUSIONS

With the establishment of the Convention, Argentina's production on DDL shows an increased number of publications visible in WoS and, at a slower pace, an increase in the complexity of the topics approached. A gradual incorporation of new dimensions in the analysis is observed, among which the production-rangeland association stands out; however, medullary contributions regarding socioeconomic and political dimensions are yet to be seen. Still, even though the studies considering socioeconomic dimensions are few in number compared with the national total, it must be pointed out that compared with the Spanish case (also considered in this special issue), the trends in Argentina are encouraging. The data show that there is a critical mass of researchers and institutions devoted to the study of desertification in the country and alliances with foreign researchers. In turn, the eco-regions showing critical desertification processes are being widely analysed at present, and this is related to the existence of research centres and researchers focused on studying the topic in these regions. Nevertheless, the analysed databases fail to reflect an important number of national-level studies, published in Spanish in Argentinean and Latin American books and in scientific journals that are not indexed in international databases.

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08

Farmers's soil knowledge, perception and management in Las Vegas agricultural district, Madrid, Spain

FARMERS'S SOIL KNOWLEDGE, PERCEPTION AND MANAGEMENT IN LAS VEGAS AGRICULTURAL DISTRICT, MADRID, SPAIN.

Society & Natural Resources

Submission Confirmation

Thank you for your submission

Manuscript ID	USNR-2015-0297
Title	FARMERS'S SOIL KNOWLEDGE, PERCEPTION AND MANAGEMENT IN LAS VEGAS AGRICULTURAL DISTRICT, MADRID, SPAIN
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Date Submitted	10-Oct-2015

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ABSTRACT

Sustainable soil management (SSM) depends on knowledge. Spanish soil science focuses on explaining soil degradation processes and impacts, but has paid less attention to traditional soil knowledge (TSK) held by farmers, despite being key stakeholders in soil conservation.

A sample of 120 farmers of a semiarid district of Madrid was interviewed in order to identify their knowledge about soil conservation and management. Farmers identify visually recognizable physical factors and those chemical factors clearly affecting productivity. Less recognized are factors like salinity or pH that require laboratory analysis. Soil knowledge is influenced by farmers' main source of income, gender, education and age. While there is a high degree of correspondence between scientific and TSK, some gaps were identified, notably with regard to erosion.

Involving public institutions, increasing agricultural prices and improving communication, education and public awareness were identified as key steps to promote farmers' adoption of SSM practices.

KEYWORDS: Desertification, Farmer's perception, Local knowledge, Mediterranean region, Soil management, Spain.

1. INTRODUCTION

Feeding nine billion people by 2050 is one of the most important challenges facing current and future generations (Godfray et al. 2010). Maintaining healthy agro-ecosystems is key to guaranteeing a sufficient flow of quality food (Boelee 2011). Global change is bringing uncertainty in different socio-ecological dimensions (climate change, biodiversity loss, energy and freshwater availability) crucial for sustainable agricultural production (EC 2011; FAO 2011; Stringer et al. 2011; Vermeulen et al. 2010).

When addressing future food scenarios the emphasis has frequently been on productivity-enhancing factors (crops and animals improvement, irrigation, fertilization, pest controls Tilman et al. 2002). Conserving and sustainably managing soils, the basis for food production, has received less attention (Bouma and McBratney 2013). However, soils play a key role in seven out of nine planetary boundaries (Rockström et al. 2009; Steffen et al. 2015). In fact, in recognition of the importance of soils for society the United Nations (UN) Assembly has declared 2015 the International Year of Soils (FAO 2014).

The European Union (EU), with over 40% of its territory devoted to agriculture, has more arable land per capita than other regions. The close relationship between soil quality and availability and food security has been recognized by European institutions (EEA 2015). Although most European soils are remarkably resilient when compared to other parts of the world, they are subject to a number of degradation processes, including compaction, erosion and loss of organic matter (Chemnitz et al. 2015). Soils in the Mediterranean region stand as the most vulnerable within the EU (Schröter et al. 2005), being particularly affected by erosion and desertification.

Soil quality and management are important components of agricultural production function, as can be seen by the attention that farmers pay to them (Brunner et al. 2008). Yet, the study of the traditional knowledge of rural communities has paid more attention to aspects like biodiversity, climate and general landscape knowledge than to detailed knowledge of soils held by farmers (Bouma et al. 2012).

Spain is part of the European-Mediterranean region prone to desertification processes (MMAMRM 2008), where soil and other environmental factors significantly limit agricultural productivity (García-Ruiz 2010; Zalidis et al. 2002). When addressing these issues, Spanish soil research is rooted in a science and technology-based knowledge (Barbero-Sierra et al. 2015) that tends to be more reductionist than the traditional, holistic and applied farmers knowledge (Lima et al. 2011).

These two sources of knowledge have been described as know-why (scientific) and know-how or tacit knowledge (traditional) (Lundvall and Johnson 1994; Ingram 2008). While the complementarity between both of them has been acknowledged (Barrera-Bassols and Zinck 2003; Barrera-Bassols, Zinck and Van Ranst 2009), research on farmers' knowledge has centered on how they adopt scientifically designed management practices rather than their own, empirically developed knowledge (Calatrava Leyva et al. 2007; Rodríguez-Entrena and Arriaza 2013).

In this paper we analyze soil management, knowledge and perception among farmers in a semi-arid, soil vulnerable district of Madrid (Spain). The objective is to assess to what extent TSK matches with science-based knowledge. We also explore possible knowledge gaps and needs expressed by farmers in order to improve the sustainability of current soil management practices in the region.

2. STUDY AREA

Las Vegas agricultural district, southeast of Madrid, contains 23 municipalities with a total area of 1379 km^2 and a population of 157,528 inhabitants (IE 2014).

It is a semiarid territory with an average yearly temperature of 15ºC and 340 mm rainfall (AEMET 2015; Botey Fullat et al. 2013). It is crossed by the Tajo (Tagus) River and two of its tributaries (Tajuña and Jarama) that have carved the Miocene (Tertiary) sedimentary plateau, resulting in a rolling landscape of generally moderate slopes. Altitudes range from 489 to 761 m.a.s.l.

These geological and geomorphological traits have combined to create a complex edaphic mosaic with a diversity of soil types (Xerochrept and Xerothent according to the USDA-NRCS soil classification) (Fernández González et al. 2013). The quaternary soils on the rivers' terraces ("vega" in Spanish, hence the name of the district) tend to have surface irrigation, offering the most productive conditions for horticultural crops and maize. Poor and stony soils are occupied with olive groves and vineyards, whereas rain-fed cereals, leguminous and other annual crops thrive on intermediate quality soils. A few pockets of natural secondary and planted forests dot the landscape occupying the most marginal land. The area is subject to desertification processes compounded by soil degradation and erosion (Bienes Allas et al. 2001).

Although the region is formally considered a rural area agriculture is very marginal, employing only 2.6% of the active population. This is due to the effects of a rural-urban dynamics promoting young occupation in alternative, mainly tertiary sector jobs, and generating high expectations of land development as an effect of urban sprawl (Barbero-Sierra et al. 2013).

3. METHODOLOGY

A structured questionnaire was developed in order to collect information related to agrarian practices emphasizing those relevant for soil management. It was organized into five main blocks that included: a characterization of the interviewed and her/his farm; a listing of management practices; an identification of potential soil-degradation activities; an assessment of the farmer's capabilities to mitigate soil degradation; and knowledge acquisition and sources of information.

The responses were codified in nominal, ordinal and quantitative variables. Open questions were subsequently categorized. Four main groups of agricultural practices that influence soil quality and productivity were considered for each of the main crops present in our area: tillage (Melero et al 2011; Holland 2004), soil amendment/fertilization (Desbiez et al. 2004; Odendo et al. 2010), irrigation (Jacobsen et al. 2012; Molden et al. 2010) and pest control (Homma et al. 2012; Riah et al. 2014). With regard to tillage, farmers were asked whether they used shallow tillage, deep tillage, no tillage and/or cover crops. Management of soil fertility was assessed through the use of plant residues, manure and other organic fertilizers, the burning of crops' organic waste, chemical fertilizers, crop rotation and fallow. In case of irrigation, this was reported as surface, sprinkle and drip. Biological and chemical pest controls were also identified as they have different effects on soil chemistry and biodiversity. This information was requested for each of the main groups of crops.

A total of 97 farmers were randomly contacted through agricultural offices in the Las Vegas district. The sample was completed with 23 interviews following a snowball approach (Faugier and Sargeant 1997). The farmers were introduced to the purpose of the research and their consent was requested prior to administering the questionnaire. Altogether 120 farmers (84%

males and 16% females) representing 10% of Las Vegas farmer population were interviewed during the period of May to September 2014.

Young farmers (officially applied to those below 40 years age) represent 17% of the sample; 57% are aged between 40 and 65 years old, with the remaining 26% above the retirement age of 65. The gender and age distribution is similar to that recorded for Las Vegas in the 1999 Spanish Census of the agrarian population, the last census with district-level reporting (INE 2002).

Descriptive statistics, parametric and non-parametric tests, regression models and multivariate (principal component and clusters) analyses were conducted using SPSS v.21 (IBM Corporation 2012) and PCORD v.6 (McCune and Mefford 2011).

4. RESULTS

4.1. Farmers' profile

Forty-eight percent of interviewees declared agriculture as their main source of income. Of the 52% for which agriculture does not represent the main source of income, this is provided by the tertiary sector, pensions and secondary sector, in decreasing order. The reasons for involvement in agriculture were grouped into three categories: family tradition (82%), vocation (12%) and others (6%).

The most common crops are olive groves, rain-fed cereals, irrigated cereals, vineyards and horticultural crops, in decreasing order. Farmers tend to manage different crops, combining on average three of them. The most common combination is olive groves, rain-fed cereals and vineyards. Rain-fed and irrigated cereals tend to be associated with full-time farming (χ^2 = 19.118 and 12.236 respectively; $p < 0.001$), while olive groves and vineyards do not show a clear preference.

Only 8% of respondents have received formal professional training or academic education related to agriculture. They tend to learn their profession through family tradition and practice. When new or specific knowledge is required, farmers rely mainly on other family members or neighboring farmers (27%), agricultural extension services (26%), the internet (14%), information provided by commercial brands (12%) or agrarian associations (10%) and marginally from specialized press (4%), consultants (4%) or other resources (3%).

4.2. Soil-related management practices

Olive groves and vineyards, resilient to yearly climatic variations, tend to occupy less fertile soils. They are related to low-impact management practices (no-tillage, cover crops and biological pest control). They also relate to crops' organic waste burning, a traditional practice that is legally permitted for these kind of crops, but is forbidden for herbaceous, yearly crops (figure 1). Some vineyards have recently been transformed from traditional rain-fed to trellis systems suitable for drip irrigation, thus stabilizing production and saving labor costs (Ruiz-Pulpón 2013).

Rain-fed cereals (wheat, barley, oats, rye) are also major crops. They tend to occupy better quality soils, maintain the traditional practices of crop rotation and fallow, and are associated with more intensive agriculture (shallow and deep tillage, chemical fertilizers, pesticides). They are also associated to the burial and recycling of organic matter from the crop, as burning is legally forbidden.

Maize is also important, being intensively managed and having surface or sprinkler irrigation. Small horticultural crops are scattered across the territory; they are irrigated and use manure to create human-made soils. A number of marginal crops (fruit trees, alfalfa, pastures and forest plantations) were grouped under the heading 'other crops', not showing a clear management pattern due to its diversity (figure 1).

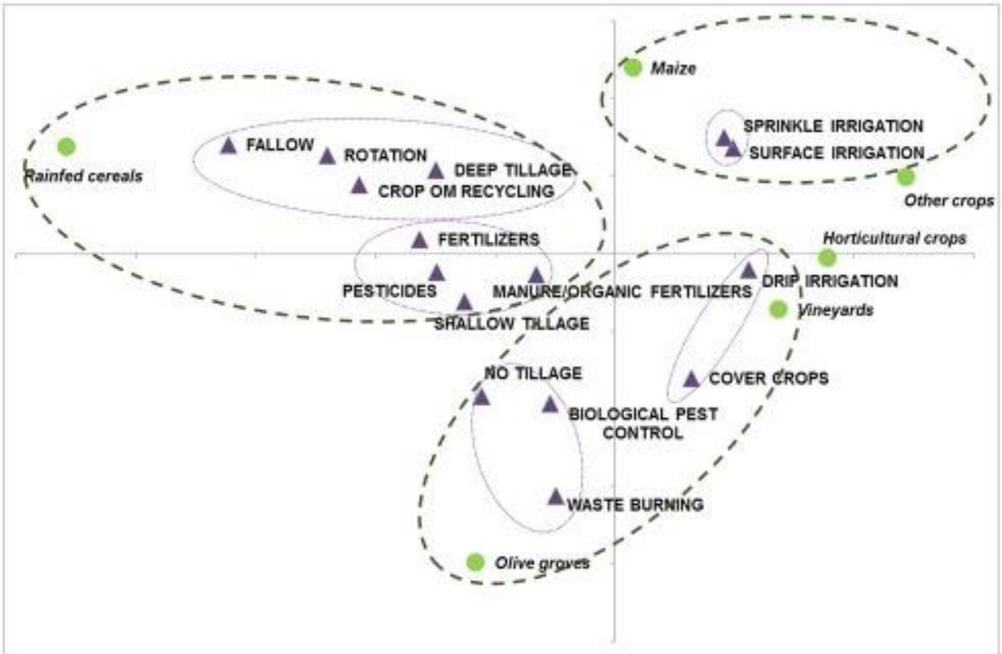

Figure 1. Principal Component Analysis for crops (dots) and management practices (triangles). Variance of axis I = 46.4%; axis II = 29.3%. A two-way cluster analysis produces three main joint groups of crops and management practices (------ dark green color) and five management practices subgroups (······ purple color).

4.3. Soil knowledge and perception

Farmers were asked about soil limiting factors that may affect their fields. Each factor was assessed in an ordinal, 1 to 4 scale (non-existing, marginally relevant, relevant, and very relevant). The frequency and intensity of the 11 limiting factors identified by farmers appear in figure 2A. The crossing of frequency and intensity defines four different conditions (figure 2B): factors that are rare and of little relevance (salinity and acidity); of little relevance but frequent (pollution, waterlogging and erosion); rare but highly relevant (alkalinity); and those factors that are both relevant and frequent (low organic matter, water retention and fertility, steep slopes and soil compacting).

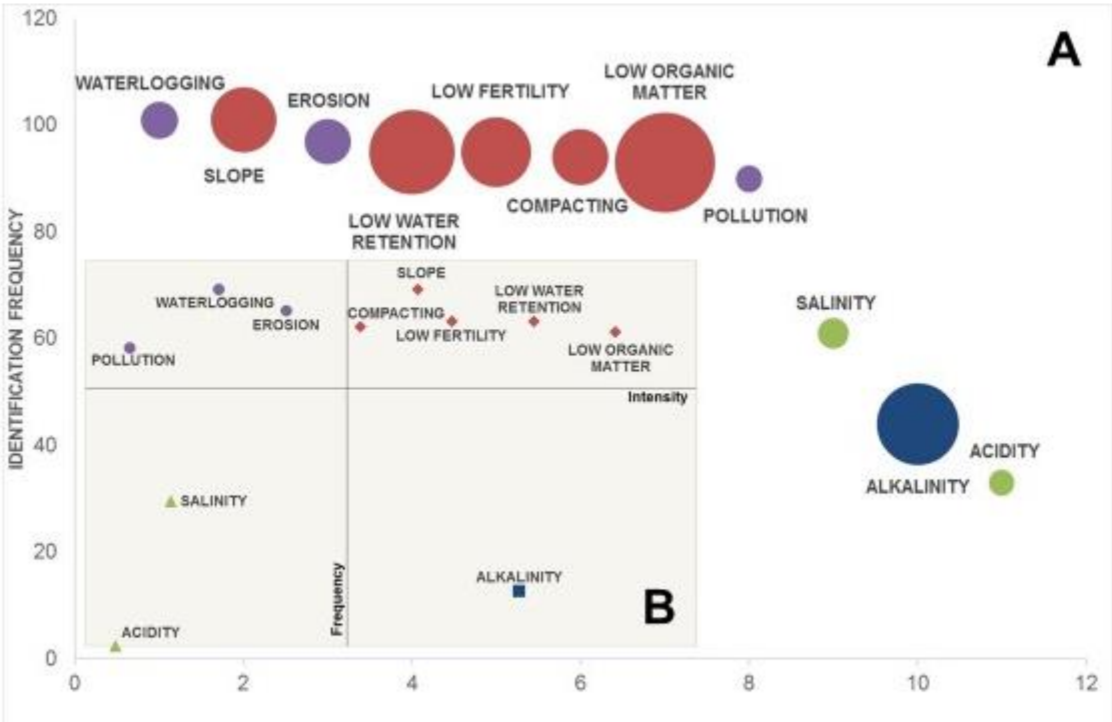

Figure 2: A) Bubble chart of the soil degradation factors acknowledged by farmers. Bubble size represents the average factor's relevance. Bubble color indicates the factor's category according to the crossing of frequency and intensity charted in B.
B) Frequency (y-axis) and intensity (x-axis) of soil degradation factors identified by farmers. Four quadrants are defined: Green triangles: rare - little relevance. Purple dots: frequent - little relevance. Dark blue squares: rare - high relevance. Red diamonds: frequent - relevant.

Since farmers only identified those soil factors about which they were knowledgeable, the number of factors mentioned by each farmer can be used as a proxy for the degree of soil-related knowledge. Farmers identified on average 7.5 factors out of a maximum of 11 (SD=3.28). We have used a generalized lineal model to assess the factors that influence that degree of knowledge. We use the Akaike Information criteria (Akaike 1981) to select the optimal model, summarized in table 1. Having agriculture as the main source of income and being male have a positive, significant effect on the degree of soil knowledge; education level has some positive effect, whereas age has a small, insignificant negative effect.

Parameters estimation

Parameters	B	Standard error	Hypotheses test Wald chi square	df	Sig.
Intercept	5.483	1.5332	12.791	1	.000
Male	1.627	.7623	4.553	1	.033
Female	0[a]				
Main income from agriculture	1.778	.5804	9.382	1	.002
Main income NOT from agriculture	0[a]				
Level of studies	.544	.2550	4.551	1	.033
Age	-.023	.0209	1.257	1	.262
Scale	8,946[b]	1.1798			

Table 1. Summary statistics of the Generalized Lineal Model: farmer's soil-related knowledge (response); gender and source of income (factors); education and age (co-variates). R^2 =0.15; p<0.001

[a] B is set to 0 because this parameter is redundant, as it is implicit in the alternative category for that dichotomous variable.

[b] estimation of maximum likelihood.

4.4. Soil improvement options

Farmers were asked about their views on the possibility of conserving and improving soil quality. Seventy nine percent replied positively to this question. The questionnaire differentiated between direct farming options for soil conservation and improvement and the enabling factors that could facilitate the implementation of these options, such as institutional and price support, among others.

Direct farming options were requested through an open question and the replies were subsequently grouped into six categories. The use of organic matter is the most frequently mentioned practice. This fact tallies with the oft-mentioned perception of a lack of organic matter as the main soil-limiting factor. Other suggestions include the change of tillage practices, fertilization and the levelling off of fields.

Three main enabling factors that would help to manage soils more sustainably were proposed in the questionnaire. Training, with 41% of replies, was the most mentioned, followed by technology (31%) and financial support (28%).

Farmers were also asked to freely identify other enabling factors. Improvement of legal and institutional frameworks, better agricultural prices and improvement of the quality of agricultural inputs were the most mentioned factors. Other factors related to policy (regulation flexibility, land concentration, raising awareness), practical issues (edaphic analysis) or farmer's organization (associations) were also mentioned.

5. DISCUSSION

Las Vegas agricultural district constitutes a complex, mosaic-like landscape derived from the diverse livelihood strategies of farmers. These strategies rest on a traditional pattern of crops, responding to edaphic diversity and allowing for a buffering of climatic and market fluctuations (Berkes et al. 2000; Rushemuka et al. 2014).

This landscape is cultivated by a combination of full and part-time farmers that, as in many other European regions, is aging and male-dominated (Brandth 2002; Rey Benayas et al. 2007). Becoming a farmer is a process assisted by family roots that facilitate access to professional knowledge and land (Gonzalez and Benito 2001). In this case study, tradition and vocation appear as the main reasons for working in agriculture. Crops and soil management are learnt from family and local networks (know-how), supporting the findings of Ali (2003), with formal agricultural training affecting only a small percentage of the sample. Aside from family and local networks, when searching for specific information, farmers tend to rely on agricultural extension services and the internet, in line with similar findings by different authors (Just and Just 2001; Riesenberg and Obel Gor 1989; Warren 2004; Zijp 1994).

Different management practices are associated with different crops. Olive groves and vineyards, the two main permanent crops, which tend to be grown in more marginal land, have less intense soil interventions (Loumou and Giourga 2003; Ruiz-Colmenero et al. 2013). No tillage and biological pest controls are common. The environmental restrictions that they experience have opened up an opportunity for some of them to be re-oriented to a focus on quality, benefiting from organic and other labeling schemes (Soler et al. 2002) as well as enjoying EU funding.

Cereals tend to be cultivated in better soils; when irrigation is possible, a combination of maize and horticultural crops appears to offer the best economic returns. These soils experience more intense interventions. Traditional soil conservation techniques like fallow (Cantero-Martinez et al. 1995) and rotation (Sánchez-Girón et al. 2004) are common, especially with rain-fed cereals; the use of deep periodic ploughing, fertilizers and other agrochemicals are the norm.

There is clear agreement among the interviewees in the identification of key agricultural constrains related to edaphic, geomorphological and water availability factors. Unsurprisingly, these constrains tend to coincide with those identified in scientific and technical reports (know-why) of the area studied (Bienes Allas et al. 2001). A similar situation has been reported in other studies in Bangladesh (Ali 2003), Rwanda (Rushemuka et al. 2014) and China (Subedi et al. 2009). However, contrary to what is acknowledged in the above-mentioned literature for this region, our results indicate that farmers do not highlight soil erosion as a significant problem. Erosion is a continuous, slow variable influencing soil (Reynolds et al. 2007). Brunner et al. (2008) found that farmers tend to associate erosion to extreme events rather than perceiving it as a continuous process. This, coupled with the short-term costs incurred when combating erosion, tends to dissuade farmers from implementing erosion control measures (Hein 2007). In spite of this, farmers in our study area use traditional erosion control measures like contour tillage.

Surprisingly, 37% of farmers recognize alkalinity as a key limiting factor, reaching the third highest score (2.23) in their assessment (above, for example, soil fertility), whilst not being recognized as a significant problem in technical reports in the region (Bienes Allas et al. 2001). This may reflect the patchy nature of soils in our area and the highly-fragmented structure of land tenure that implies with it the possibility of having a plot under these conditions. The alkalinity of soils, although infrequent in this region, is a serious obstacle for the crops, particularly vineyards (Reyes et al. 2006), something that is well known by those farmers that have a plot of land affected by it. This seems to correspond to a rare but spread-across phenomenon that has left an imprint in farmers' perception.

The degree of knowledge about soil-related factors is relatively high, with most farmers identifying visually recognizable physical features like erosion, soil compaction and waterlogging (Desbiez et al. 2004; Mairura et al. 2008; Price 2007). Some general chemical factors affecting productivity (fertility, organic matter) as well as agriculture-related soil pollution (for which farmers receive occasional official reports in compliance of current legislation) are also commonly recognized. Less recognized are chemical factors related to salinity or pH that would require chemical analysis (Ryder 2003).

Economic dependence on agriculture, gender, education and age all affect soil knowledge (Nainggolan et al. 2011; Pyrovetsi and Daoutopoulos 1999). Farmers who derive most of their income from agriculture show a significantly higher degree of edaphic knowledge. Men also tend to have more knowledge than women, a fact likely related to the traditional gender divisions in agricultural labor in Spain (Camarero 2011; Cruz Sousa 2006).

The level of education also has an effect on knowledge (see Ingram 2008, for a similar finding in England). This is compounded by the very limited formal opportunities of technical training in agrarian schools (occupational training or university degrees, that some of our interviewees hold; see CAM 2015). Age has a marginal negative effect, probably related to education and new information technologies that tend to be more accessible to the younger generation (Bouza 2003).

Soil knowledge and conservation awareness match with an optimistic view (79% of respondents) about improving soil quality through the implementation of SSM, in line with similar findings in other regions of Spain (Calatrava Leyva et al. 2007). There is a strong correspondence between the soil degradation factors identified and the direct measures (e.g., manure, appropriate tillage, soil fertility, field levelling-off) proposed by farmers to cope with them, a relationship that has been found in a wide array of regions (Ali 2003; Desbiez et al. 2004; Ingram 2008; Lima et al. 2011; Mairura et al. 2008; Price 2007; Quansah et al. 2001; Rushemuka et al. 2014). This reinforces the idea that farmers have a good understanding of soil quality and its appropriate use, the main obstacles to more sustainable management practices being costs and other enabling factors (Price 2007; Shiferaw, Okello and Reddy 2007; Calatrava Leyva et al. 2007).

Among these enabling factors, the policy framework is approached with a dual perspective. On the one hand, farmers require policies and incentives that help them to orientate their practices, such as: cheap/free access to soil analyses and assessment; technical and policy support to facilitate an economic use of some biomass waste like vine and olive tree twigs and branches; and training in order to shift to organic farming. On the other hand, farmers underscore the rigidity of some measures like the prohibition of the burning of stubble, a traditional and affordable pest control practice (Virto et al. 2007). While there is an awareness about the positive effect of reducing risk of fire, farmers suggest more flexible regulations that allow for occasional controlled burning that reduce incidences of pests, accelerate mineralization and reduce tillage costs.

In line with the findings of Shiferaw et al. (2007) and Barrett (1991), a common complaint in our sample is that the increased short-term costs of better soil management practices are not matched by the prices obtained for their yields. This fact is particularly relevant in the context of the increasing share of management costs in Spanish agricultural sector (MAGRAMA 2015).

Improved soil management is hindered by a land tenure based on many small, scattered plots. An already longstanding and recurrent topic is the need for a land consolidation scheme (Naylon 1959) that would reduce management costs and allow for full use of available land that sometimes is abandoned due to this dispersion of plots. Unlike in many other rural areas of Spain where land concentration was widely promoted by the National Land Concentration and Rural Planning Service (subsequently incorporated into the IRYDA, National Institute for Land Reform and Rural Development; Maurel Bosque 1984), land concentration was poorly implemented in Madrid region. This is due to the urban sprawl of Madrid conurbation and the subsequent pressure to develop agricultural land, resulting in high expectations for windfall profits (Barbero et al. 2013; Cavailhès and Wavresky 2003; Gallardo and Martínez-Vega 2009; Hewitt and Escobar 2011; Martínez-Fernández and Esteve 2005;).

Finally, it is worth mentioning the spontaneous recognition by farmers of the need to increase their own awareness of soil improvement and conservation. The need for communication, education and public awareness strategies about soil conservation has been stressed by different authors (Calatrava et al. 2010; Cameron 2003; Ingram 2008; Power et al. 2013; Pyrovetsi and Daoutopoulos 1999).

6. CONCLUSION

The semiarid Las Vegas District (SE Madrid Region) maintains a scarce-but-engaged rural population in spite of the biophysical and socioeconomic constraints affecting agriculture. Farmers have a shared, concrete local knowledge and traditions (‘know how’) offering them a good understanding of soil properties and suitable management practices. This knowledge largely coincides with the scientific ‘know why’ edaphic assessment of the area. However, a critical gap related to erosion has been detected.

Farmers tend to be aware of soil conservation problems and the possibility of improving soil management practices. However, their actual implementation is limited by short-term cost considerations.

In this sense they have a contradictory attitude towards agrarian institutions, which are perceived with some mistrust due to their regulatory and controlling roles but also with high expectations as providers of technical and economic support. Our findings suggest that a combined package of training, policies and incentives would be required in order to match farmers’ needs and expectations in relation to SSM.

This package of measures has already been mentioned in the Spanish Desertification Action Plan (NAP); however, until now they have not been developed further. Revamping the Spanish Desertification NAP in order to make it effective and linked to farmers’ needs and perceptions seems an essential step for the country that has the highest desertification risks and faces the most severe climate change challenges in Europe.

7. ACKNOWLEDGEMENTS

This study was funded by the Applied Research and Extension Agrarian Service of IMIDRA through the project FP-13: Agrarian employment and sustainable agriculture. A case study in Las Vegas Agrarian District. We would like to thank the farmers who shared their time and knowledge with us, as well as to Vanessa Sánchez Maldonado and Rodrigo Fernández-Mellado Madrazo for their support and advice during the interview period and to Daniel Harper for the English editing. We also like to thank the warm reception offered by the agricultural extension offices.

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09

Analysing perceptions, attitudes and responses of winegrowers about sustainable land management in central Spain

LAND DEGRADATION & DEVELOPMENT
Land Degrad. Develop. **26**: 458–467 (2015)
Published online 20 March 2015 in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/ldr.2355

ANALYSING PERCEPTIONS ATTITUDES AND RESPONSES OF WINEGROWERS ABOUT SUSTAINABLE LAND MANAGEMENT IN CENTRAL SPAIN

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Received: 2 December 2014; Accepted: 2 December 2014

ABSTRACT

This study provides a better understanding of the perspective and attitudes of farmers towards sustainable land management (SLM) practices in central Spain. Farmer's willingness to change from conventional tillage to cover crops in vineyards is seen as an indicator for adoption of sustainable agriculture. Two complementary approaches were used: open interviews ($n = 25$) and surveys ($n = 64$). The portrait of these winegrowers is of mature farmers, owners of their lands and conscious of soil erosion problems (81%), although not on their own lands. They observe soil degradation (45%); however, they are more conscious of problems in their vines or grapes (64%). Only 32% would be willing to use cover crops to avoid erosion. The barriers for adoption were mainly related to water constraints, lack of knowledge and inability to accept production decreases. Results indicate an underlying lack of information on SLM. They show confusion or mistakes regarding the relationship between tillage and erosion. Young farmers are more prone to change practices. Scientific results are not effectively communicated; there are no efficient local structures to provide them with knowledge and advice in their work, including guidance on environmental issues. The EU agri-environment payments cover the costs of SLM practices for avoiding erosion or compaction and increasing SOC. In spite of that, participants do not apply for subsidies to compensate the income foregone. Policy makers, extension services and scientists have to face this situation to tackle the limited knowledge transfer revealed in this study.

KEY WORDS: cover crops; land degradation; environmental policy; farmers' perception; erosion

INTRODUCTION

Farmers are small in number (5% of total employment in the EU-27, Archive of European Integration (AEI), 2012); however, they are the most important managers of the landscape: around half of the EU's land is farmed. Farmers' behaviour has a significant impact on environment, and this behaviour can be strongly influenced by their knowledge and perception (Ferguson & Bargh, 2004) of environmental issues. There are many publications regarding soil conservation and degradation, but the points of view of land users are not so frequently addressed (Kelly *et al.*, 2009). Particularly in Spain, little attention has been paid to farmer's environmental knowledge (Oñate & Peco, 2005; Garrido Fernández, 2006; Calatrava *et al.,* 2011). Importantly, the knowledge and attitudes provided by farmers could help in a better-suited implementation of policy measures in agricultural soils. The study of the view or perception of stakeholders is growing as it is the scientific interest on the social, economic and biophysical views of the Earth System, and especially the perceptions of citizens and society (Karltun *et al.,* 2013; Nabahungu & Visser, 2013; Sop & Oldeland, 2013; Pereira *et al.,* 2014; Vila Subirós *et al.,* 2014).

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Agricultural land in Spain is currently threatened by soil erosion (Cerdà *et al.,* 2009), loss of soil organic carbon (SOC), decreased biodiversity and compaction (COM (2006) 231). Particularly, vine farming is one of the agricultural activities that currently puts pressure on Spanish soils. Vineyards cover 963 095 ha of the 7 060 245 ha in the world in 2012 (http://faostat.fao.org/). It is one of the pillars of the economy in many regions in this country.

Vines are resistant to drought and thrive well in poor soils (Van Leeuwen & Seguin, 2006). They are therefore frequently cultivated in marginal lands. Vines can produce grapes for more than a century, although production diminishes after several decades, while wine quality may increase (Robinson, 2006). Because of this longevity, traditional practices based on frequent tillage lead to land degradation because of the resulting large areas and extended periods of unprotected bare soil. As a result, soil degradation has been frequently described in grape producing areas.

One of the most frequently used indicators to assess land degradation and production threat is soil erosion. Cerdan *et al.* (2010) compiled a large database of erosion rates under various land use types in Europe. They found that erosion rates in bare soil were the highest ($15{\cdot}1\ \mathrm{Mg\,ha^{-1}\,yr^{-1}}$), followed by vineyards without conservation measures ($12{\cdot}2\ \mathrm{Mg\,ha^{-1}\,yr^{-1}}$). In Spain, the next figures of soil loss ($\mathrm{Mg\,ha^{-1}\,y^{-1}}$) can be found: 0·3 (Arnáez *et al.,* 2012), 3·3–162 (De Santisteban *et al.,* 2006), 5·9 (Ruiz-Colmenero *et al.,* 2013), 18–22 (Ramos & Porta, 1997), 25 (Ramos & Martinez-Casasnovas, 2009), 30 (Casalí *et al*., Casali *et al.,* 2009), or 44 (Lorenzo *et al.,* 2002). Therefore, tolerable soil loss, ca. 1 $Mg\,ha^{-1}\,yr^{-1}$ (Morgan, 1995; Verheijen *et al.,* 2009) is frequently surpassed. Consequently, pollution spreading is also an important concern for copper (Fernández-Calviño *et al.,* 2013) or nitrogen (Novara *et al.,* 2013).

Accelerated soil erosion could diminish as has been demonstrated frequently in the scientific literature (García-Orenes *et al.,* 2012; Zhao *et al.,* 2013). There are alternatives to conventional tillage that are worth doing. They are known as Conservation Agriculture, a sustainable land management (SLM) promoting agricultural systems involving minimum soil disturbance, permanent residue soil cover and diversified crop rotation (FAO, 2008). One of these alternatives is the use of cover crops in the inter-rows of vineyards. We can find pros and cons in the literature. Erosion control has been confirmed in grassed vineyards (Casermeiro *et al.,* 2004; Durán Zuazo *et al.,* 2004; Lieskovský & Kenderessy, 2014); conservation of soil moisture is not clearly established (Celette *et al.,* 2008), but there is no doubt regarding improvements of physical–chemical soil conditions (Bochet *et al.,* 1998; Ruiz-Colmenero *et al.,* 2013); soil biodiversity, both micro and macro-fauna (Ingels *et al.,* 2005); and vine pest control (Guerra & Steenwerth, 2012). Research on organoleptic characteristics of juice and wine and vine performance in grassed vineyards is being developed and shows promising results (Warner, 2007; Lee & Steenwerth, 2013). However, the use of cover crops entails costs; this includes man power, cost of seeds or new machinery. Policy measures can counteract these drawbacks.

In this context, policy makers are committed to encompassing economic and environmental needs. Since 2000, agri-environment payments have been part of the EU's rural development approach. They are based on two principles: (i) payments are for additional costs and income foregone as the result of agri-environmental commitments and (ii) the decision to apply for it being voluntary for farmers. In 2003, in the framework of the Common Agricultural Policy (CAP), common conditions were established for direct payment, not linked to the level of production, but rather linked to good agricultural and environmental conditions (Council Regulation (EC) 1782/2003). In addition, structural measures for supporting rural development were established (Council Regulation (EC) 1698/2005). Payments were granted only to farmers who make agri-environmental commitments on a voluntary basis (Art. 39). This includes, for example, avoiding erosion and soil compaction, conservation of SOC and conservation of habitats. The current national law concerning these matters in Spain (*Real Decreto* 486/2009) supports the use of vegetation covers in permanent crops (Annex II). Although a case by case study is necessary, the corresponding regional regulation establishes payments for organic vineyards from €266 to €513 ha^{-1} (producing wine or table grapes respectively). Moreover, those growers working on less favoured areas with sloping lands can obtain a compensatory allowance from €25 to €250 ha^{-1}, with a maximum of €4000 per holding. Are these payments enough? It is worth examining the costs and benefits of vine-growing activity.

Globally, depending on the vine variety and crop density, harvests usually yield between 5 and 20 Mg of grapes per hectare. In Spain, according to a review of production of red wines (Fernández Alcázar, 2011), the yield is approximately 6 $Mg\,ha^{-1}\,yr^{-1}$ on average, and the cost of producing grapes (bush or trellis training systems) is around €3400 $ha^{-1}\,yr^{-1}$. Costs include fertilisers, pesticides, machinery, depreciation and taxes. The national official prices of most common red grapes range from €0·50 to €1·0 kg^{-1} (BOE No. 13, 15 January 2011). If an average price is considered (€0·75 kg^{-1}), the vine grower can obtain a profit of €1100 $ha^{-1}\,yr^{-1}$.

Cover crops involve additional costs, which derive from the work needed to sow and mow covers, the cost of seeds and the drop in production. The cost of sowing and mowing is neutralised by less tillage, which is carried out only once (before sowing) when using cover crops, instead of three times (at least) in conventional management. The cost of seeds is variable, for example, Ruiz-Colmenero *et al.* (2011) reported different prices ranging from €49 $ha^{-1}\,yr^{-1}$ (€0·7 $kg^{-1}\,yr^{-1} \times 70\,kg\,ha^{-1}$ of *Secale Cereale L.*) to €60 $ha^{-1}\,yr^{-1}$ (€1·5 $kg^{-1}\,yr^{-1} \times 40\,kg\,ha^{-1}$ of *Brachypodium distachyon* (L.) P. Beauv.). These authors also found an average drop in grape production of 20% in cover crops treatments. Considering this loss of income, farmers would earn approximately €200 less per hectare yearly.

If the aforementioned figures are taken into account, the subsidies provided for environmental measures – based on additional costs and income foregone – are considerable. In spite of it, vineyards in Spain are mainly managed by tillage, actually, different kinds of tillage. The most common is minimum tillage (66·4%), followed by a so-called traditional tillage, deeper and more frequent (22·8%), and by the use of spontaneous cover, concentrated in humid regions in northern Spain (5·2%). Less than 0·2% of vineyards are managed by sown cover crops (Ministerio de Agricultura Alimentación y Medio Ambiente, 2012).

The aim of this study is to analyse why this SLM in vineyards is not used more frequently. We gathered information on the different management practices of winegrowers in central Spain, as well as their opinions about erosion problems in their vineyards and their willingness to change from tillage to cover crops as a proxy indicator for adoption of SLM.

MATERIAL AND METHODS

Study Area, Natural, Social and Economic Description

The area studied is located in the centre of Spain (Figure 1), in rough outlines it is a semiarid area, with 360–500 mm of annual rainfall, and average temperature ranging from 14 to 15 °C (25 year-average, National Institute of Meteorology). The area corresponds to the Cambisol soil Order, dominated by marls and limestones. These calcareous soils are widely distributed in Mediterranean semiarid climatic conditions.

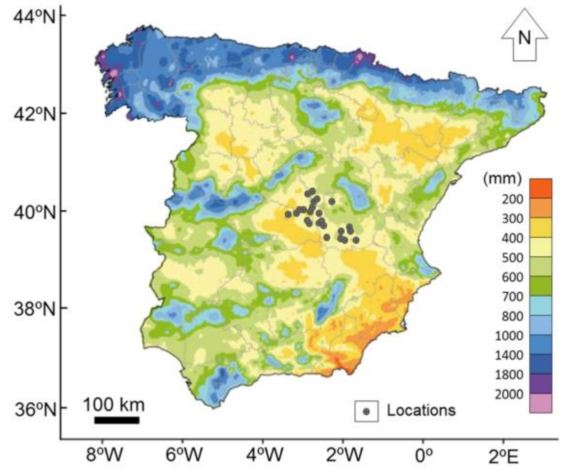

Figure 1. Location of vineyards of respondents, a semiarid area in central Spain. The colours in the figure represent the average total annual precipitation. Map modified from AEMET (in Spanish: Agencia Estatal de Meteorologia). This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

They are productive soils widely used for cereal, wine and oil production. Vines and olive trees, being more tolerant to shallow soils, are usually displaced towards sloping lands in order to allow flat and better soils for cereal production.

The population density within the study area is between 12 and 69 inhabitants per km^2 in Castilla-La Mancha (CLM) and Madrid regions, respectively. The service sector (60–65%), mining, industry and energy (17–19%) and construction (12–16%) are the areas' principal economic activities, whereas agriculture is carried out by 5–6% of the population.

In Spain, vineyards account for the 5·5% of arable land; in Madrid region, this figure corresponds to the 4·6% and in CLM to 12·6% (Agricultural Census of the Annual Directory of Spain in 2012). The use of cover crops in vineyards in these regions is almost nonexistent: less than 0·1% in CLM and negligible in Madrid (Ministerio de Agricultura Alimentación y Medio Ambiente, 2012). There are ca. 28 000 winegrowers according to the associations of protected designation of origin of Madrid (2759) and CLM (25 098) (Source: Ministry of Agriculture 2010–2011). In this study, vineyards were located in Aranjuez, Arganda del Rey, Belmonte del Tajo, Brea del Tajo, Campo Real, Cenicientos, Chinchón, Colmenar de Oreja, El Herrumblar, Fuenlabrada, Fuente el Saz, Iniesta, Ledaña, Madrid, Morata de Tajuña, Navalcarnero, Paracuellos del Jarama, Peralveche, San Fernando de Henares, San Martín de Valdeiglesias, Serracines, Tielmes, Titulcia, Torremocha del Jarama, Valdelaguna, Valdilecha, Villagarcía del Llano, Villalbilla, Villalpardo and Villanueva de La Jara (Figure 1).

Data Collection

A two-stage process to collect data was carried out. Firstly, 25 winegrowers were contacted amongst those who had previously collaborated with the research team and their acquaintances. This group participated in open interviews. In these long conversations, lasting 1–2 h, the interviewees expressed their opinions about agriculture, soil erosion and land management practices. The information obtained was used to know in depth their points of view on the one side, and to prepare a structured questionnaire on the other side.

In the second-stage, a survey was conducted. A total number of 64 winegrowers, different from the previous 25 interviewees, agreed to answer the questionnaire. They were contacted thanks to the collaboration of winegrower cooperatives and regional extension centres in the area of study. The questionnaire was formed by 23 questions, closed and open ended (Table I). Questions were responded both face by face and by phone. Three categories of information were collected in accordance to Newing (2011): (i) basic characteristics of respondents: personal attributes such as age, location and land tenure; (ii) information on knowledge: opinions about soil erosion, perception of soil or crop degradation or environmental concerns; and (iii) information on behaviour: adoption of conservation farming, terraces, mulching and cover crops. This information was used as a proxy for adoption of SLM.

Data Treatment

Descriptive statistics were used to analyse quantitative data of surveys, and results were presented either as percentages or counts. A chi-square test was used to determine if there were differences between variables. The results were tested for significance at $p \leq 0{\cdot}05$. A multivariate analysis of information gathered from the survey was performed considering all the variables, transformed into categorical responses being 1 as affirmative responses and 0 as negative or not answered. The principal component analysis (PCA) results in an orthogonal subspace after reduction of the dimensions of data sets, which captures the main structure of the data. Analyses were run in STATISTICA 6.0 (Statsoft Inc. Tulsa, OK. USA).

RESULTS AND DISCUSSION

Because of the relatively few number of respondents in this study, the results do not necessarily represent the opinion of winegrowers of the region or the country. Nevertheless, they form a heterogeneous group of varying ages and experience who have similar perceptions, attitudes and responses regarding environmental problems.

The Profile of Farmers, Basic Characteristics of Respondents

The 25 interviewed respondents were all male, in the average age of 50 years old. Their profile or opinions on environmental problems were not analysed from a quantitative point of view; however, some statements deserve attention and are literally included in the results. As mentioned, the total number of winegrowers responding the questionnaire was 64. They were contacted in extension centres and cooperatives in the harvesting period, when they carry the grapes to the cellars. As they were quite busy in that moment, they were also asked to be interviewed by phone later on, but the

Table I. Questionnaire responded by 64 farmers.

1. For how long have you been producing grapes? … years	13. (Only for respondents using cover crops) If you use cover crops, are they … ? Three options: spontaneous, planted or artificial and DN/RF
2. How big is your vineyard? … hectares	14. (Only for respondents with sloping lands) Do you receive any institutional aid to control soil erosion? Three options: Yes, No and DN/RF
3. Did you inherit your vineyards? Three options: Yes, No and DN/RF	15. Do you think that tillage is a useful technique to reduce soil erosion? Three options: Yes, No and DN/RF
4. Is your vineyard organic? Three options: Yes, No and DN/RF	16. Would you like to receive information to control soil erosion? Three options: Yes, No and DN/RF
5. Is viticulture your sole economic activity? Three options: Yes, No and DN/RF	17. Do you think that soil erosion may influence wine quality? Three options: Yes, No and DN/RF
6. (Only for those having other activities) Which one is it? Six options: independent professional, tourism, building, retired, other (please explain) and DN/RF	18. In a recent scientific experiment in vineyards in the Region of Madrid, it was established that cover crops increased soil organic matter and efficiently prevented erosion. Nevertheless, they reduced grape production between 15 and 25%. Would you change to cover crop in your vineyard under these circumstances? Three options: Yes, No and DN/RF
7. Did you notice some of these facts or episodes in your vineyard? Eight options: rills or gullies, sediment accumulation, changes in the colour of soil, increase in soil strength or compaction, more stoniness, other (please write), none of them and DN/RF	19. (Only for respondents saying no) If you would not change, could you explain why? (You can choose maximum three options) Eight options: It is too expensive, it reduces production, there is a competition for water, I don't know how to manage it, it needs too much care, there is a risk of weed invasion, other (please explain) and DN/RF
8. Did you notice any of these effects in your harvest? Six options: low production, vines look bad, more fertilisers are needed, other (please explain), none of them and DN/RF	20. Do you think that soil erosion is a problem or it can be a problem in the future? Three options: Yes, No and DN/RF
9. What proportion of your vineyard is in a sloping area? Six options: none, less than one quarter, between one quarter and the half, more than the half, all and DN/RF	21. Who is responsible for soil conservation regarding erosion? (only one answer) Eight options: the farmers, the agricultural technicians, the local government, the regional government, the state government, all of us, nobody and DN/RF
10. (Only for respondents with sloping lands) Do you use terraces in order to control soil erosion? Three options: Yes, No and DN/RF	22. How old are you? … years old
11. Do you use mulch in the inter-rows to avoid soil loss? Three options: Yes, No and DN/RF	23. Where is your vineyard (municipality)? Village: …
12. (Only for respondents with sloping lands) Do you use cover crops in order to control soil erosion? Three options: Yes, No and DN/RF	

DN/RF, don't know or refused to answer.

majority of them declined to participate. Hence, just some 5% of the potential vine growers of these cooperatives were willing to participate in the survey. From the 64 participants, 23 responded *in situ*, filling the questionnaire and 41 responded by phone.

The corresponding χ^2 analysis of the survey between the two studied regions showed that there was just one significant difference: the number of organic farmers that was higher in Madrid ($\chi^2 = 8{\cdot}2$; $p = 0{\cdot}004$; $df = 1$). Nevertheless, other characteristics such as age, sloping areas or land tenure were similar. In spite of this difference in organic management, responses were alike regarding environmental issues.

The mean age of respondents was 46 ± 16 years old. Indeed, 44% of them can be considered young farmers as they are under 40 years old according to the Council Regulation (EC) No 1698/2005 of 20 September 2005. They are not beginners in this business as 43% have been farming for more than 15 years, 37% for 5–15 years, and only 19% are new vine growers, having been harvesting grapes for just 5 years.

Taking the size of their vineyards, some 30% used land measuring less than 10 ha, 64% measuring greater than 10 ha and 6% who did not know or refused to answer.

Most respondents inherited their lands (75%). Nonetheless, this is not their only income source: up to 72% have other work, which diminishes their competitiveness. This second business is generally agricultural: growing cereal, olives or raising livestock (46%). Some others are also involved in activities not related to agriculture (43%). Finally, 11% are retired but continue working their lands. This profile matches the figures provided by the Labour Service Surveys indicating that a very small number of people work in agriculture on a full-time basis. Arguably, this can have an impact on the willingness to protect soil, which can be less important if it is not the main livelihood activity.

Information on Knowledge

From the information obtained in the interviews, farmers were especially concerned about economic returns; this has not changed from previous studies (Garrido Fernández, 2006). Environmental problems were focused to eventual hazards because of pollution. They usually mixed different environmental issues, for example, droughts, climate change, water pollution by fertilisers or pesticides, air pollution by carbon dioxide or urbanisation. Farmers also complained about the lack of knowledge of their own soils, considering that soil analyses are difficult to be obtained and are expensive.

Soil and land problems were identified as loss of fertility; soil loss was barely mentioned on one's own initiative. However, all the farmers had some areas of their lands on slopes, although they were not able to provide their exact gradients. This fact impedes further quantitative analysis in this study, and it may be developed in the future as other studies found the slope gradient to be the main factor to move farmers to change to SLM in olive groves (Franco & Calatrava, 2006).

Considering the 25 interviews, three groups can be differentiated according to their perception of soil erosion as a driving force of land degradation. The first group (six interviewees) had not a clear stance, they declared certain environmental concerns and also lack of knowledge.

- '*Land degradation takes a very long time*, *it's difficult to know whether soil erosion has influence on crops*.'
- '*If we use no-tillage we will have to use herbicides*, *and this is worse*.'
- '*Soil is going to be always there*, *but that tree is a pity*, *it has unearthed roots and it's going to fall down*, *it's a pity*.'

The second group of farmers (nine interviewees) was aware of environmental issues and prone to adopt SLM practices. When they were asked about erosion, they exhibited their consciousness about it:

- '*Erosion is evident after big storms*, *you can see the grooves formed after that*.'
- '*Sometimes I see the soil moving from one place to another*.'
- '*Even in less steep lands*, *water creates its own paths*. *Erosion is above all due to water*, *not to wind because it's a clayey soil*.'
- '*Some vines are suffering in bad soils*, *they are smaller and produce less*.'

This group mentioned the influence of the passage of time in the process of land degradation:

- (erosion) '*It is not important in the short run*, *but after generations it must be noticed*, *a lot*.'
- '*Soil erosion is there*, *but changes caused by erosion are not so dramatic to be seen in the short term*, *I'm not going to see them*.'
- '(…) *probably my sons will not inherit this land*, *but I would like to leave it to anyone who may think that someone before him took care of soil*.'

Moreover, they are conscious about the relationship between soils and crops; all these opinions were stated by farmers aged less than 50 years old. They think that wine quality can be linked to soil erosion:

- '*If soil erosion means loss of fertility*, *then*, *nutrient loss must influence wine quality*.'
- '*It must affect the wine because the vines suffering erosion are less productive*.'
- '*The roots of vines are unearthed*, *therefore*, *they cannot obtain nutrients needed for high quality wine*.'
- '*Erosion matters because what happens to soil*, *happens to wine*.'

This concerned group is made of organic winegrowers and owners of cellars who have recently entered in this sector. They declare that they do not need subsidies, as they would use SLM practices even without them:

- '*Honestly*, *in this dry region* (Madrid), *not being organic is a sin*, *it is costless.*'

The third group (10 interviewees) considered that soil erosion is not a problem at all; they represent the knowledge of conventional farmers. The term 'conventional' is used in this study to describe farming relying on highly mechanised and chemical inputs approaches, and as the opposite of organic farming. Their views are illustrated in these words:

- '*Soil erosion is important only because of media pressure*.'
- '*Soil erosion has always existed*, *it is something natural*.'
- '*Soil erosion is not a risk for me*.'
- '*What is important is pollution*, *or the* CO_2, *not the soil loss*.'

One opinion emerges from the last group: soil conservation is not a priority in vineyards, and this is in line with the general belief that best wines are produced through moderate water deficit in soils with limiting factors, such as reduced soil depth, high pebble content and low water holding capacity (Dry & Loveys, 1998; Pellegrino *et al.,* 2006; Van Leeuwen & Seguin, 2006).

These farmers would adopt cover crops to control erosion only if an improvement of wine quality – so price – would be demonstrated. This group thought that there is no relationship between soil erosion and wine quality because

- '*The less soil moisture*, *the higher quality of wine*, *with less production*.'
- '*The worst the soil is*, *the higher quality is obtained for wine*.'
- '*Soil erosion does not influence wine because the roots of vines are deep*.'

Several obstacles were mentioned by conventional farmers for adopting the use of covers: lack of knowledge, lack of tradition for such practices in the region, water competition, weed invasion, fire risk or complex management. For example, they do not want to increase labours for seeding or mowing covers, they would need new machinery, and they think that costs may increase due to seeds, herbicides, pesticides or labours. Possible pests in the vineyard as a consequence of covers were also brought up, singularly the spider bite (*Tetranychus urticae* Koch). However, demonstrated benefits of cover crops in vineyards as an important component of integrated pest management (Altieri & Al, 1995; Sharley *et al.,* 2008; Danne *et al.,* 2010) were not mentioned.

All these farmers (25) normally obtained the agronomic or environmental information from other farmers, agricultural supply companies, extension agents or technicians from cooperatives. Their opinions regarding information meetings are negative:

- '*If you organise an information meeting with a barbeque you can bring together many farmers in one place. But this is not enough, because motivation is needed.*'
- '*If an expert provides information for farmers, this information is not for the speaker to make an impression. We have to understand that the speech is useful for us, and provides benefits. Speakers have to walk in the farmer's shoes.*'
- '*They are useful if they demonstrate benefit, I only believe what I see.*'

These general ideas were transferred to the questionnaire. When they were asked about problems in their soils (questions 7 and 8, Table I), 55% of respondents did not find any degradation (Figure 2). Those perceiving soil problems reported mainly compaction and rills or gullies, followed by change in soil colour, more stoniness or sediment accumulation.

As mentioned before, sloping topography is usual for vineyards in this study area. In fact, 56% of the respondents affirmed having some or all land on slopes. The winegrowers with sloping vineyards tend to perceive soil degradation more often, 50% of them doing so, instead of 38% for those who have flat vineyards.

Winegrowers are sensitive to changes in their vines or grapes. The percentage of growers observing soil degradation versus observing problems in their vines goes from 45% (Figure 2) to 64% (Figure 3). They describe lower yield, the need for more fertilisers, or poor appearance of their vines.

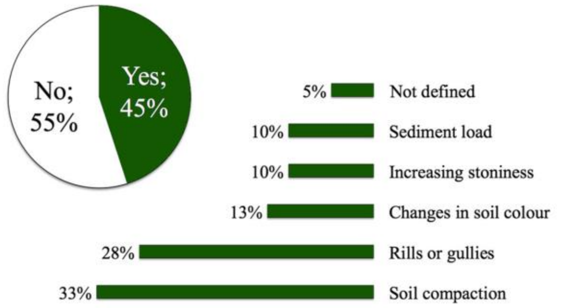

Figure 2. Percentage of farmers perceiving problems in their soils, and how they did notice these problems. Results of survey regarding question 7 ($n = 64$). This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

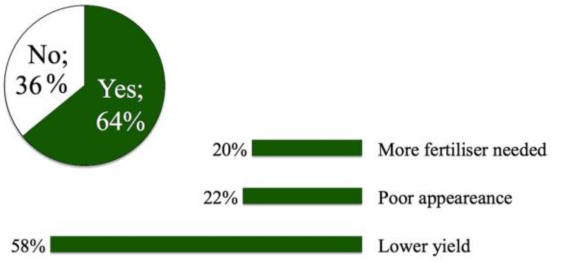

Figure 3. Percentage of farmers perceiving problems in their crops, and how they did notice these problems. Results of survey regarding question 8 ($n = 64$). This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

With regard to the 56% of farmers having their vineyards in sloping lands, management practices to achieve soil conservation are based mainly in structures such as terraces (33%), the use of cover crops (21%) and mulching (10%) (Figure 4). From the 13th question, the preferred cover crops are spontaneous vegetation, as only one farmer declared the use of seeded crops. Only 3% receive subsidies related to measures to control erosion.

Concerning the 15th question: '*Do you think that tillage is a useful technique to reduce soil erosion*?', 58% responded affirmatively and 18% did not know or refused to answer. Only 24% were aware that soil tillage can contribute to soil erosion. Indeed, this result can be explained by the experience of farmers: as soon as practicable after heavy storms they have to plough their soil to remove rills; otherwise, further rainfalls will deepen the rills and therefore increase soil loss as a result of the increased connectivity caused by rills and gullies (Bennett *et al.,* 2000).

Most of the growers (more than 75%) would like to receive more information about soil erosion and its control. It is also significant that 60% of respondents think that soil erosion can be related to wine quality, even if this cause–effect relationship has not yet been completely established.

Information on Behaviour of Farmers

The most important reason for changing their tillage practices to cover crops is illustrated in this response of

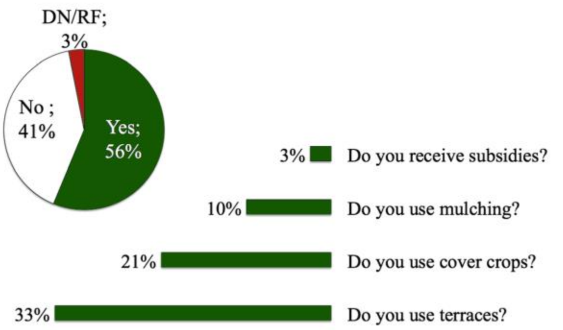

Figure 4. Percentage of farmers working with sloping soils, and what management practices were used to prevent erosion. Results of survey regarding questions 9–16. ($n = 39$) (DN/RF = don't know or refused to answer). This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

interviewed conventional farmers: '*What's in it for me*?'. When asked about their way to control erosion in sloping vineyards, they mentioned different practices: they use manure to restore depleted soil, they build terraces, they avoid mouldboard plough and they try to avoid ploughing downhill, even if they consider this to be more difficult. Nevertheless, if they have to choose between orientation (north–south is the best one to maximise the hours of light) and slope, they will choose orientation, even if they have to plough in the slope direction. However, in this region, sunlight hours are not a limiting factor. Frequently, the group of conventional winegrowers mentioned their helplessness to avoid soil erosion:

- '*It is really difficult; I only try to make contour ploughing in a way and time to avoid runoff.*'
- '*I have no means to do so.*'
- '*We are so short of money that we will not accept any changes if this means cost increases.*'

They also have the feeling that agriculture will last only for a short time, particularly near big cities due to urban sprawl.

Farmer's behaviour is also influenced by their lack of personal motivation:

- '*Actually, farmers don't like their work.*'
- '*They do it just because they have no choice.*'
- '*Their sons will not inherit their lands.*'
- '*I only know one farmer really passionate by his job. The rest work in agriculture out of sheer necessity. They don't like it. They come here to exploit, just to exploit.*'
- '*Farming is not valued by society.*'

Only two recent winegrowers interviewee were using cover crops to control soil moisture; they tried to reduce tillage, but they did not mention erosion benefits. They said that good farming practices were not especially difficult to follow, but they complained about environmental policy, particularly with regard to the excessive bureaucracy to obtain subsidies. As was observed in other Spanish regions, they apply for subsidies for economic reasons rather than for environmental purposes (Oñate & Peco, 2005; Calatrava *et al.,* 2011).

From the questionnaire, we can confirm that in spite of the problems observed in soil and production, the majority is not willing to change their usual practices. In the question 18th, participants were informed about a research project showing the benefits of cover crops on SOC and erosion, but a decline in grape production. Only 32% of respondents were willing to change to cover crop in these circumstances, 20% did not know or refused to answer and 48% were reluctant to change.

Integrated Information: Principal Component Analysis

A multivariate analysis was performed to obtain integrated information of responses obtained from the 64 participants of the survey. Variables placed close to each other influence the PCA in similar ways, which indicates they are correlated. The two principal components of this analysis extracted 30% of the variance. Although this can be considered low, the model is able to separate the main group of respondents saying *Yes* to the question about their willingness to change or not (Figure 5).

The first principal component absorbs the largest variance (17%). The variables defining this component are related to the need for information, the ability to observe soil degradation and the willingness to change (Figure 6). The respondents of this group with steep vineyards tend to think that tillage is a good option to fight erosion. The opinion of young farmers is close to this group. Other authors in Spain found that young farmers were more willing to adopt SLM (Calatrava *et al.,* 2005).

The responses of the older winegrowers (more than 65 years old) working full-time on their land are found on the right side of the first axis; therefore, their willingness to change is weak. According to recent statistics about rural development in Europe (http://ec.europa.eu/agriculture/statistics/rural-development/2012/), elderly farmers account for more than 65% of farm holders in Spain. Their opinion is therefore important, as they are seen as the source of knowledge for new generations of farmers. The results of PCA regarding their attitudes match the conversations with the older winegrowers during the open interviews, because they were reluctant to invest in their vineyards. In their opinion, viticulture has no future, and the land will very probably be transformed for urbanised use. This feeling can be explained by the model of economic development based on new construction in this country (Barbero-Sierra *et al.*, 2013).

In the survey, the number of these old winegrowers (>65) was small, constituting just seven (11%). Nevertheless, it is worth mentioning that they have particular opinions about the questions of the survey compared with active younger winegrowers. Only one of these old farmers observed soil degradation, and consequently, he was the only one willing to change to SLM practices.

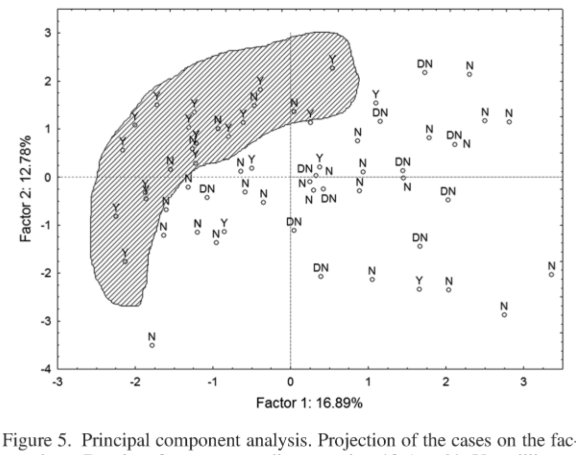

Figure 5. Principal component analysis. Projection of the cases on the factor plane. Results of survey regarding question 18 ($n = 64$; Y = willing to change to cover crops; N = not willing to change; DN = Don't know or refused to answer).

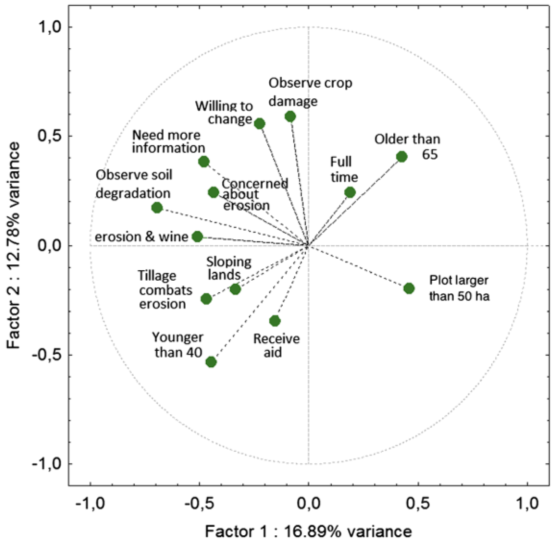

Figure 6. Principal component analysis. Projection of the variables on the factor plane. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

In order to determine if the age of respondents was significant, they were divided in two groups: those under versus those above 40 years old (Table II). We found that younger winegrowers (64% of the sample) perceived soil problems better than the older ones (36%). Both have the same opinion about the use of tillage to prevent erosion and the need for more information.

Figure 6 determines that the low willingness to change is also related to the larger size of vineyards in the PCA analysis. The increase in plot size is convenient for obtaining more production by means of mechanisation of labour. It has been argued that big landowners are usually little concerned by erosion because they may abandon their lands once degraded; furthermore, erosion problems seem to be relatively rare on smallholdings (Roose, 1996). This trend is confirmed in this analysis, although the sample is not big and other studies found different results. In France, big landowners do show interest in no-till techniques in their vineyards, especially because the CAP calls for higher quality, downsizing production and protection of fragile land. In the open interviews, those having cellars or high quality wine producers usually had the opinion that SLM is the best way to achieve long-term profits from the land. This contradiction, between the survey and the interviews, shows the need for further studies to know whether or not the size of lands influences the attitude of winegrowers.

In this study, 87% of respondents have plots smaller than 50 ha. The younger farmers with smaller plots are more prone to change to SLM (Läpple & Van Rensburg, 2011), probably because it is easier for them to observe changes in their soils and crops as was found in this study. Respondents who want more information are at the same time concerned about erosion, to the point where they consider that erosion has an effect on wine quality. In the open interviews, the winegrowers stated that they will assume extra costs, only if this means later economic benefits. This can be achieved only if the relationship between SLM and wine quality is demonstrated.

The detailed reasons for the respondents not being willing to change are frequently based on the lack of water under dry climates for rain fed crops (21%); their lack of knowledge regarding cover crop management (14·8%); their inability to accept a decrease in production (10·6%); the higher costs presumed for the cover crop management (8·5%); the added time spent on this management (8·5%); the possible proliferation of weeds (8·5%); their age, as they are going to retire soon (4·3%); their satisfaction with the present situation of their soil and crops (only 2·1%); and finally, 21·3% are not giving any explanations.

When they were asked in an open question of the questionnaire (21st question), 'Who is responsible for soil conservation regarding erosion?', some of them thought that farmers had an important role (33%), but they also mentioned the state (14%), and the local authorities (8%) or the extension agents (4%) as elements that should be involved in these issues. Yet, most of them thought that this was a shared responsibility of society as a whole (41%).

In this general context, policy makers are involved in the process of implementation of SLM practices through enacting regulations such as environmental payments to avoid erosion, but in the questionnaire, 85% of respondents declared not having applied for any type of aid related to this concept. Only 3% of respondents received this aid (Figure 4), and the remaining 12% did not answer.

Table II. Answers grouped according two groups of age (under and above 40 years old).

	Winegrowers under 40 ($N = 22$)	Winegrowers above 40 ($N = 39$)	Significant differences between two situations. Chi-square 95% confidence ($df = 1$)
Aware of soil degradation	64%	36%	$\chi^2 = 4{\cdot}358$; $p = 0{\cdot}037$*
Aware of damage in production or vines	55%	69%	$\chi^2 = 1{\cdot}316$; $p = 0{\cdot}251$
Think that soil tillage prevents erosion	79%	63%	$\chi^2 = 1{\cdot}498$; $p = 0{\cdot}220$
Receive subsidies for erosion control	8%	0%	$\chi^2 = 1{\cdot}664$; $p = 0{\cdot}197$

The total number of respondents was 64, but three of them refused to answer this question; the information in this table was drawn from 22 + 39 = 61 respondents.
df = degrees of freedom.
*Significant differences.

Policy measures are powerful incentives to farmers for avoiding land degradation (Louwagie *et al.,* 2011), but there are several weaknesses in the successful implementation of environmental measures (Calatrava *et al*., 2011); results show that dissemination of good practices to provide guidance for these farmers seems to be low. 'Farmers are crucial to the success of agri-environmental schemes, and without sufficient understanding and financial incentives, the policy will not be adequately implemented' (ECA, 2011; p. 48). Financial incentives seem to be enough, but in this region, understanding of environmental problems is still a pending issue. Use of SLM is most effective when these are understood, and decisions are rooted in land and resource stewardship and long-term concerns about health of the farm and the soil (Ahnström *et al.,* 2009).

CONCLUSIONS

In spite of the fact that soil is the base of production for farmers, this is not its main environmental concern. This fits in with the little or no intention of changing management practices found in this study. Only 32% of respondents were willing to change to cover crops. This fact may be interpreted as unwillingness to adopt SLM, and, consequently, as a source of concern for policy makers committed to the application of environmental measures of the CAP, and also as a source of frustration for scientists, whose research is not applied.

From a policy perspective, there are two ways to promote SLM: economic support and awareness raising/education. According to the data, the first one seems to be enough, although not sufficiently used by farmers. The second way, education of farmers about environmental issues, is often ignored. The fact that only 24% of respondents be aware of the risks of tillage for soil erosion is worrisome. Efforts must be concentrated to increase the flow of scientific information. There are improvements as farmers declare knowing good farming practices, but they are reluctant to use them if there are no returns. These conflicts between personal profits and general benefits can be mitigated by educational programmes on environmental issues designed for farmers. Local meetings and demonstrations involving farmers are needed, for example, to demonstrate the relationship between SLM practices and quality of products. '*I only believe what I see*' illustrates the importance of these demonstrations. In Spain, the number of extension centres to carry them out has decreased in the past decades and should be relaunched.

A larger survey is currently under way to clarify gaps and weaknesses found in this study concerning the slope of lands or the farm size. Nevertheless, the recruitment of adequate numbers of people to participate is not easy. It is important to emphasise that the willingness of farmers to participate in this kind of environmental surveys is scant. Farmers in this region may still be guided by productivist attitudes and still seeing environmental measures as a threat to their livelihood. These attitudes should push policy makers and scientific community to increase efforts to transfer scientific knowledge and remove barriers between stakeholders with the aim to develop conservation policies.

ACKNOWLEDGEMENTS

This study was funded by the Ministry of Research and Science (Reference RTA2007) and the Regional FP-2012 Programme. We thank the wine cooperatives for their collaboration: Vinícola de Arganda, San Isidro de Belmonte Bodega Cooperativa San Roque, Cooperativa Vinícola San Andrés; Vinos Jeromín SL, SAT-1431 San Estéban Protomártir; SAT-2906 Don Álvaro de Luna; and SAT-2900 El Arco y SAT-008 Viña Bayona. We also appreciate the helpful suggestions of reviewers.

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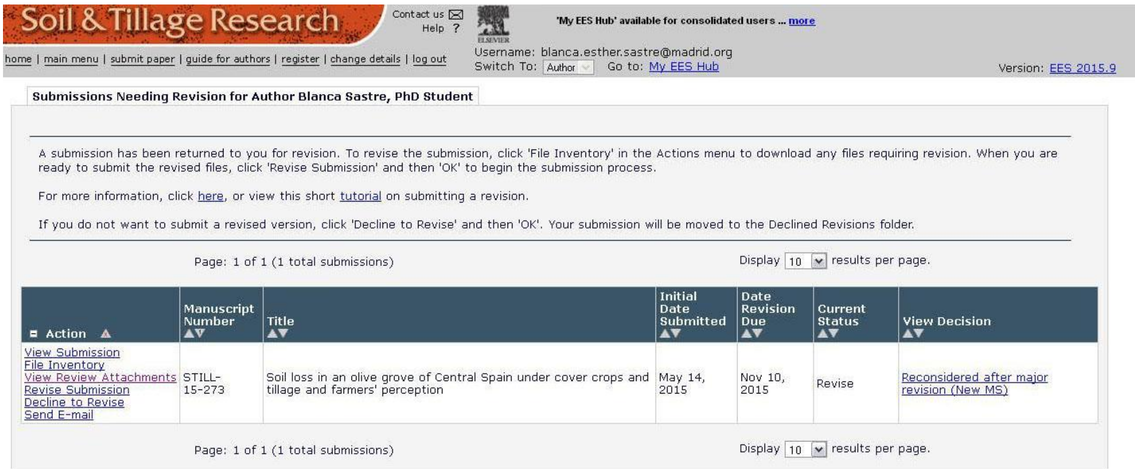
10

Soil loss in an olive grove of central Spain under cover crops and tillage and farmers' perception

SOIL LOSS IN AN OLIVE GROVE OF CENTRAL SPAIN UNDER COVER CROPS AND TILLAGE AND FARMERS' PERCEPTION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ABSTRACT

This study evaluates soil loss due to water erosion in microplots. During four hydrological years, we assessed 4 cover-crops treatments in a sloping olive grove of Central Spain, planted on a marl gypsum soil under semiarid climate. The treatments were: tillage, two annual covers (*Hordeum vulgare* and *Onobrychis viciifolia*/*Vicia ervilia*) and a permanent cover (*Brachypodium distachyon*). Tillage showed the highest soil loss (6.8 t ha-1 year-1). Annual cover crops showed more soil loss than the permanent one (1.4 t ha-1 year-1). Soil loss depends on soil coverage and kinetic energy of rainfall events. Vegetation cover higher than 40% in autumn and spring was essential to limit soil loss, even under heavy events. The sediments mobilised were enriched in SOC and clay. In spite of the well known benefits of such crops in soil, local land users don't use it. A lack in environmental education and awareness has been detected[16].

KEYWORDS: cover crops; olive grove; soil erosion; microplots; farmers' perception.

[16] Abbreviations
Barley: HOR
Leguminous: LEG
Purple false brome BRA
Control CON

1. INTRODUCTION

There are more than 28000 ha of olive groves in the Madrid Region (MAGRAMA, 2013). Although it is not an important amount in the total Spanish olive grove surface ($2.5 \cdot 10^6$ ha, mainly in Andalucía), it is considered important in the south of Madrid as they occupy 20% of the agricultural area of the region, being the second in agriculture extension after cereals (IECM, 2013).

As the other Spanish traditional olive groves, the madrilenian olive trees are placed in sloping areas, on poor and shallow soils (Gómez *et al*., 2009b). Ninety eight percent of olive groves in the region are rainfed, 93% are planted with a low density (less than 200 trees$\cdot$ha^{-1}) and 80% are usually tilled to reduce competition for water (MAGRAMA, 2013). This conventional practice results in a wide surface of bare soil prone to erosion processes.

More than 25% of the EU's territory is affected by water erosion (EEA, 2015). It is one of the most important processes on land degradation in Mediterranean areas due to arid conditions and high rainfall erosivity (López-Bermúdez and Albaladejo, 1990; Panagos *et al*., 2015). This is even worse in soils that are poor in organic matter and weakly structured (Panagos *et al*., 2014).

Many researchers have focused on the assessment of soil loss due to infrequent and high intensity events (García-Orenes *et al*., 2009; Ruiz-Colmenero *et al.,* 2013) or with medium intensity events (Martínez-Mena *et al.*, 2002), mobilising the largest amount of sediments per event. Few studies address low-intensity and high-frequent events which generate little by little high cumulative quantities of soil loss too (Marques *et al.*, 2008; Taguas *et al*., 2013).

Linked to the sediments generated by water erosion, some quantities of organic matter and nutrients are also lost, varying according to the study conditions (Bienes *et al*., 2010; Martínez-Mena *et al*., 2012).

Since the 90’s several studies across the world have demonstrated the efficiency of herbaceous covers in olive groves (Alcántara *et al.*, 2011; Castro *et al.*, 1991; Durán and Rodríguez, 2008; Ferraj *et al.*, 2011; Ferreira *et al.*, 2013; Francia *et al.*, 2006; Gómez *et al.*, 2009a; Márquez-García *et al.*, 2013; Martínez *et al.*, 2006; Palese *et al.*, 2014; Pastor, 1997; Saavedra, 2003). In Spain, the greatest surface of cover crops in olive groves is used in the South, in Andalusia, where they seem to be accepted by farmers. The use of cover crops in the Centre of Spain is scarce; nevertheless some studies have verified the need and suitability of alternative managements in vineyards (Ruiz-Colmenero *et al.*, 2013). Cover crops in olive groves on gypsiferous soils are not frequent. Due to the severe consequences of traditional tillage in such soils, there is a need for site specific research on the environmental consequences and social acceptance of cover crops as a useful tool for sustainable land management in the region.

The main goal of this paper is to measure the sediment yields and their physical-chemical characteristics using microplots under different soil management systems: conventional tillage and cover crops. We also have assessed the possible adoption of such management practice by the farmers of that region.

2. MATERIAL AND METHODS

2.1. Study area

The study was performed in an experimental olive grove located in southern Madrid (UTM 30N, ETRS89: X= 455654, Y= 4435959), in Colmenar de Oreja municipality (Fig. 1). The average elevation is 540 m.a.s.l. and the slope ranges from 9 to 12%.

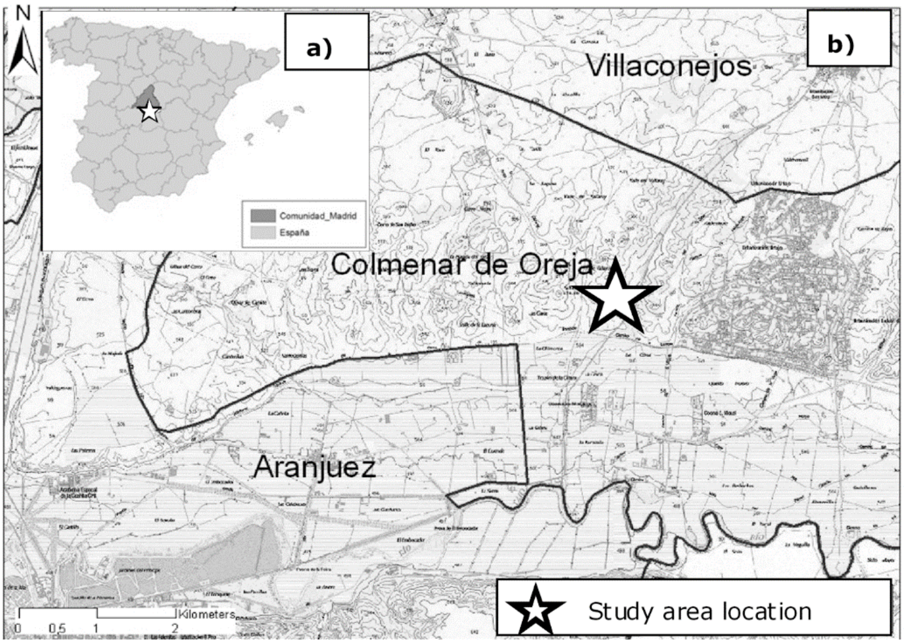

Figure 1. Study area location.

The soil is classified as Gypsic Haploxerept (Soil Survey Staff, 2014) or Haplic Gypsisol (arzic siltic) (WRB, 2014), with gypsic marls underlying soils. The moisture regime is xeric. This soil has high contents on silt and low in organic matter and clay. The upper horizon has a weak edaphic structure.

The climate is semi-arid Mediterranean, with long hot summers (quite often above 35ºC on average in July and August) and cold winters. The average annual temperature is 13.6ºC. Annual precipitation is around 390 mm (1980-2015) with high inter and intra-annual variability (Elías and Giménez, 1965; Urbano, 1992). In the last few years, the total amount of precipitation has been falling down but the intensity has been increasing in the study area (García-Díaz *et al.*, 2015).

The olive plantation was established in 2004 with trees at 6 x 7 m spacing. The cultivar is Cornicabra, the most common in Central Spain (Rallo *et al.*, 2005). It covers approximately 3 ha. They were usually managed by tillage to decrease weed competition and they are under rainfed conditions. The study started in autumn 2010 and lasted to autumn 2014.

There is an automatic meteorological station in the olive grove used to record rainfall depth which has been registered every 10 minutes. An additional HOBO pluviometer having 0.2 $mm \cdot s^{-1}$ precision provided us with rainfall intensity. The parameters we obtained from each rainfall event were: rainfall depth (P), maximum 15-minute rainfall intensitiy (I_{15}), maximum 30-minute rainfall intensity (I_{30}), maximum hourly rainfall intensity (I), kinetic energy (KE) and rainfall erosivity (R).

2.2. Olive grove management

In November 2010 all the area was plowed with a chisel to a depth of about 0.15 m. The tillage was applied in the 6 m-wide stripes, at the centre of the rows between the olive trees. Each treatment was performed in blocks of 3 consecutive rows per treatment. At that moment, the cover crops were seeded. In order to maintain the soil bare in the line of olive trees, a contact herbicide (glyphosate) was applied twice a year to the soil around the trees, covering 1m wide along the line. The treatments consisted of two annual covers: 1) barley (*Hordeum vulgare*) (hereafter HOR) seeded each autumn; 2) and leguminous (hereafter LEG): Sainfoin (*Onobrychis viciifolia*) between 2010 and 2013, but due to a progressive decline covering soil, the last year it was replaced by another leguminous, bitter vetch (*Vicia ervilia*) being seeded instead, the seeding took place at the same time that HOR; 3) permanent grass cover of purple false brome (*Brachypodium distachyon*) (hereafter BRA), that sprouts in early spring and by late June it is already mature and dry, at which point it self-sows and sprouts spontaneously again the following autumn; and 4) control (hereafter CON) consisted of one labour per year with a chisel, being 0.15 m deep, in November to control weeds. All the treatments were mowed once in early spring, except in 2013 when vegetation was mowed twice due to high vegetation growing. Plant debris was left in the surface.

2.3. Sampling procedures

Three bounded runoff microplots per treatment were established in a previous study in 2007 following a systematic distribution. Each plot was 0.5 m wide and 2 m long (1 m^2) with the long side along the direction of the maximum slope. A Gerlach trough (Gerlach 1967) was placed at the base of each plot to collect sediments. The perforated trough was connected to a pipe which carried the runoff water to a tank where suspended sediment was collected. There was a 1 mm Ø filter in the trough to retain the gross sediments and debris when the runoff was high.

Sediments (from January 2011 to September 2014) were collected at the erosion plots after each rainfall event. The sediments were oven-dried at 105ºC and weighed. Once a year, we collected the sediments from the tanks and were oven-dried at 105ºC and weighed. The weight of the dry sediment collected in the Gerlach trough is the value we used in the statistical analysis for individual events. For the yearly soil loss, we added the weight of the sediments in the tank.

Vegetation cover was determined bi-monthly in each microplot. The first year we used two methods: i) colored orthogonal pictures using Adobe Photoshop® and ii) quadrants 25 x 25 cm^2 were used with the participation of 6 trained observers, and the average value of 6 observations was obtained. We compared both methods and we obtained no significant differences, as García-Estríngana *et al.*, (2005) found previously. As colored pictures are a high time-consuming method when color differences between soil and vegetation were low (mainly from May to October), we decided to use quadrant method for the rest of the project.

To study the particle-size selective transport by water erosion, at the beginning of the research we assessed the texture composition and soil organic carbon (SOC) from 4 points of the Ap horizon (around 0.30 m deep) in the study area (hereafter Reference soil). We also analyzed the texture and SOC from ten samples of sediments from Gerlach trough of CON treatment in order to have enough amount of sediment to carry the analysis. The selected samples were set after mixing 3 random replicates of these sediments. Five of the samples were produced by moderate intensity rainfall events, and the other five by high intensity events. SOC analysis couldn't be made in 2 samples because there was not enough soil.

Particle size distribution was assessed with Robinson pipette method (MAPA, 1994) and SOC was determined using the wet chemical oxidation (Walkley and Black, 1934).

2.4. Social approach

Surveys to 120 farmers in Madrid Region have been conducted to know their willingness to use cover crops. The aim was to know their environmental understanding and awareness with regard to soil conservation issues and the impact that their olive grove managements have on soil conservation. The surveys were carried out in 2014 in different ways: i) questionnaires in Local offices and Regional extension centers where training courses were provided to local farmers; ii) telephone interviews; iii) face-to-face interviews to some of the local farmers to know in depth their perception about soil erosion problems.

The questions of a structured questionnaire were organized in three main groups: i) basic characteristics: study level, age, main activity, plot size; ii) information on knowledge regarding land degradation; iii) information on their own land management.

2.5. Statistical procedures

Statistical procedures were carried out with the software package SPSS 19® for Windows. The data should be transformed to use parametric test. A one-way ANOVA was carried out with soil parameters to assess the differences between treatments, seasons, sediments and Reference soil. A Tukey test ($p<0.05$) was used to establish significant differences between treatments and seasons. When transformations did not work, we conduct Games-Howell non-parametric test. Spearman's correlations to calculate the correlation between the measured variables. A linear regression model was used with all the variables.

3. RESULTS AND DISCUSSION

3.1. Rainfall characteristics

From November 2010 to October 2014 the annual precipitation on average was 283±40 mm·year^{-1}. These years were quite similar in monthly temperature but not in precipitation, which was highly irregular between months and years, as usual in Mediterranean climate. The driest cropping season was 2011/2012 (237 mm·year^{-1}), whilst 2012/2013 was the wetter reaching 328 mm·year^{-1}. The periods from January to June and from September to November had the largest differences, while the months of summer were quite similar with a low depth of rainfall.

We have recorded 50 rainfall events between January 2011 and September 2014, and the sediments were collected the day after when possible. Table 1 shows the main characteristics of these events. There are significant differences between seasons for P, I_{15} and KE. Spring and autumn were the seasons with the higher and heavier rain falls, whilst summer was the opposite.

Table 1. Mean and SD of the main characteristics of rainfall events on average and per season: rainfall depth (P), maximum 15-minute rainfall intensity (I_{15}), maximum 30-minute rainfall intensity (I_{30}), maximum hourly rainfall intensity (I), kinetic energy (KE) and rainfall erosivity (R).

	Average	Season			
		Autumn	Winter	Spring	Summer
N	50	14	16	16	4
P (mm)	21.9±15.1	24.7±17.5 a	21.1±13.8 a	23.8±14.7 a	8.0±4.5 b
I_{15} ($mm \cdot h^{-1}$)	8.8±6.7	11.1±10.4 ab	5.7±2.7 b	10.0±5.0 a	8.9±4.3 ab
I_{30} ($mm \cdot h^{-1}$)	7.1±4.9	8.9±7.8 a	5.2±2.1 a	7.0±3.2 a	8.7±3.4 a
I ($mm \cdot h^{-1}$)	11.3±9.1	13.1±14.4 a	7.8±3.0 a	13.3±7.5 a	11.1±6.5 a
KE ($MJ \cdot ha^{-1}$)	3.3±2.5	3.4±3.2 ab	3.2±2.1 ab	3.9±2.4 a	1.1±0.6 b
R ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1}$)	16.7±22.5	23.6±37.4 a	11.2±9.7 a	17.9±15.9 a	5.1±5.0 a

Different lowercase letters mean differences between seasons at $p<0.05$.

3.2. Sediment loss

The total cumulative soil loss by water erosion for CON treatment was 6.8 $t \cdot ha^{-1} \cdot year^{-1}$, followed by LEG (4 $t \cdot ha^{-1} \cdot year^{-1}$), two-fold than HOR and five-fold than BRA (Table 2). Those differences were statistically significant ($p<0.05$) between BRA with respect to CON and LEG, due to protective effect of permanent cover along the study period. Regarding soil loss per event CON and LEG had the highest values, followed by HOR and finally BRA. LEG was similar to CON due to the very low coverage of sainfoin on the plot during the 3 crop seasons, the coverage hardly reached 30%. HOR is in an intermediate place due to the fact that several weeks were needed until the grass reach a good coverage to protect the soil. Therefore, the soil was bare the most of the time during autumn and winter rainfalls. Once barley was fully established, the soil coverage was over 60%.

All the treatments exceeded the considered soil loss tolerable rate of 1 $t \cdot ha^{-1} \cdot year^{-1}$ (Bienes *et al.*, 2001; Verheijen *et al.*, 2009). Annual soil loss of BRA is quite close to this limit, and it is remarkable that in the last season the soil loss was 0.71±0.47 $t \cdot ha^{-1} \cdot year^{-1}$. Gómez *et al.*, (2014) found that the greatest soil loss in an olive grove of SW Spain was due to rill and gully processes (16.1 $t \cdot ha^{-1} \cdot year^{-1}$ in a five-year period). Nevertheless, in our study we cannot evaluate those processes in the microplots, so we are underestimating the total amount of soil loss. In a previous paper of our team in the same area we could realize that in a high-erosive single event, soil erosion in microplots was between 1 to 14% of the soil erosion produced in the rills of the catchment (Bienes and Marques, 2008). Soil loss up to 28 $t \cdot ha^{-1} \cdot year^{-1}$ was recorded in a bare soil in the study area under more intense rainfall events (Nicolau *et al.*, 2000).

Table 2. Mean and SD of soil loss; Reduction percentage of soil loss compared to control treatment; Mean and SD of soil loss per event.

Treatment	N	Annual soil loss ($t \cdot ha^{-1} \cdot year^{-1}$)	Reduction percentage of soil loss respect to CON (%)	N	Soil loss per event ($g \cdot m^{-2}$)
CON	12	6.81 ± 6.49 a	-	50	51.10 ± 82.51 a
HOR	12	2.74 ± 2.53 ab	59.77	50	21.09 ± 44.14 b
LEG	12	4.00 ± 2.58 a	41.26	50	31.10 ± 42.02 a
BRA	12	1.36 ± 1.58 b	80.03	50	10.03 ± 23.98 c

Different lowercase letters mean differences between treatments at $p<0.05$

Inter-annual soil loss variations due to water erosion were very important, but the differences amongst repetitions were also high. For this reason, it was difficult to find statistically significant differences for the different crop seasons between treatments.

Figure 2 shows cumulative soil loss for the study period for the different treatments and the amount of precipitation per event. The total amount of soil that has been lost in CON was 2583 g·m^{-2}, 1554 g·m^{-2} in LEG, 1056 g·m^{-2} in HOR and 471 g·m^{-2} in BRA. It can be seen that each time a high rainfall happened, soil loss went off, being more pronounced in CON. From the beginning of the research, soil loss rate of CON was higher than the cover crops. CON was still increasing at the same speed during the second crop season, while BRA was separating from annual cover crops. In 2012/2013 season, when rainfall events were more intense, the behavior of CON and BRA did not change, but LEG begun taking distance from HOR, due to the poor establishment of the sainfoin. For the last season BRA almost controlled soil erosion fully.

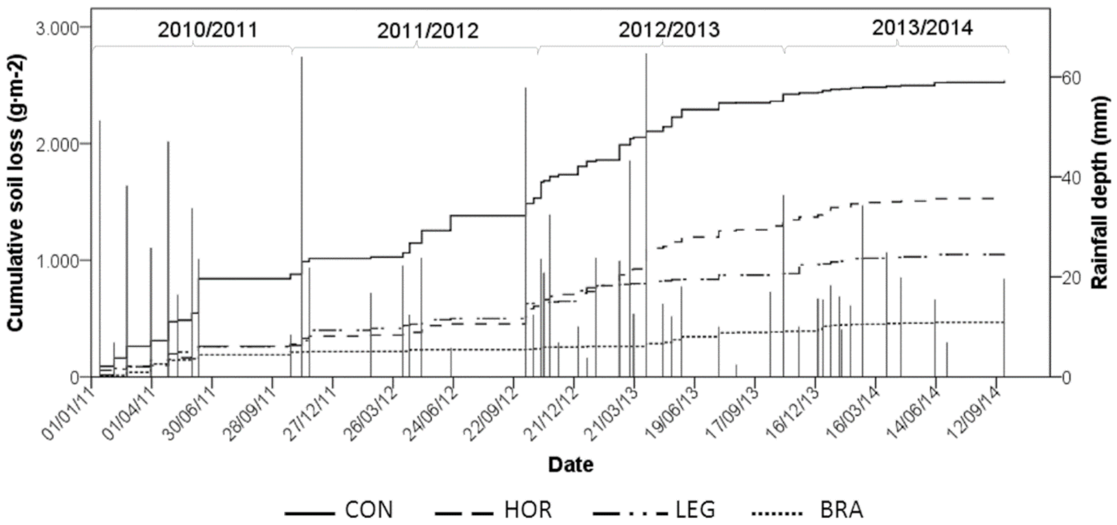

Figure 2. Cumulative soil loss (g·m^{-2}) per treatment and rainfall depth (mm) registered per event in columns.

Taking into account the mean of soil loss per season, the greatest soil loss happened during spring (Table 3) when rainfall events were more intense and erosive (Table 1). Summer and winter were the moment when less sediment was mobilized, due to less erosivity of rainfall events.

Tillage with a chisel of CON, HOR and LEG treatments were made all in November, so BRA was the unique treatment that kept protection on soil during autumn and winter. This is the reason why BRA controls erosion better than annual cover crops. In winter, the effect of tillage was still important and the annual covers had not grown yet, so only BRA reduced soil erosion, as happened in autumn. In spring HOR was established, controlling soil loss as well as BRA, LEG was an intermediate case.

If we study the differences between seasons in each treatment, CON was the only one having significant differences between spring and summer. In spring, when rainfall events were heavier, both annual and permanent cover crops were covering the soil. The coverage percentage was different, but in all cases it was enough to protect the soil from rainfall erosivity. This is the reason because it is vital to inform the land users that keeping a minimum coverage in spring and autumn will limit soil and fertility loss.

Table 3. Mean and SD ($g \cdot m^{-2}$) of soil loss per event in the different seasons.

Treatment	Seasons Autumn	Winter	Spring	Summer
N	14	16	16	4
CON	45.11±42.73 ab A	39.82±41.16 ab A	75.75±72.98 a A	25.69±28.03 b A
HOR	27.25±41.40 a AB	19.27±23.54 a A	20.30±17.44 a B	10.42±17.06 a A
LEG	33.76±30.41 a A	26.46±24.82 a A	35.85±43.32 a AB	21.32±23.10 a A
BRA	5.53±6.90 a B	5.66±8.62 a B	16.44±18.25 a B	10.09±16.21 a A
Mean	27.91±35.75 ab	22.80±29.23 b	37.08±49.26 a	16.88±20.59 b

Different lowercase letters in each row mean differences between seasons. Different uppercase letters in each column mean differences between treatments at $p<0.05$

Figure 3 shows that usually sediments were mobilized in small quantities. BRA had 75% of the records under 10 $g \cdot m^{-2}$, whilst in LEG and CON they were around 60%. CON had the highest proportion of high soil loss per event, 15% of the records were above 100 g·m-2, this amount was reduced to 6 and 5 % for LEG and HOR, and only 1% for BRA.

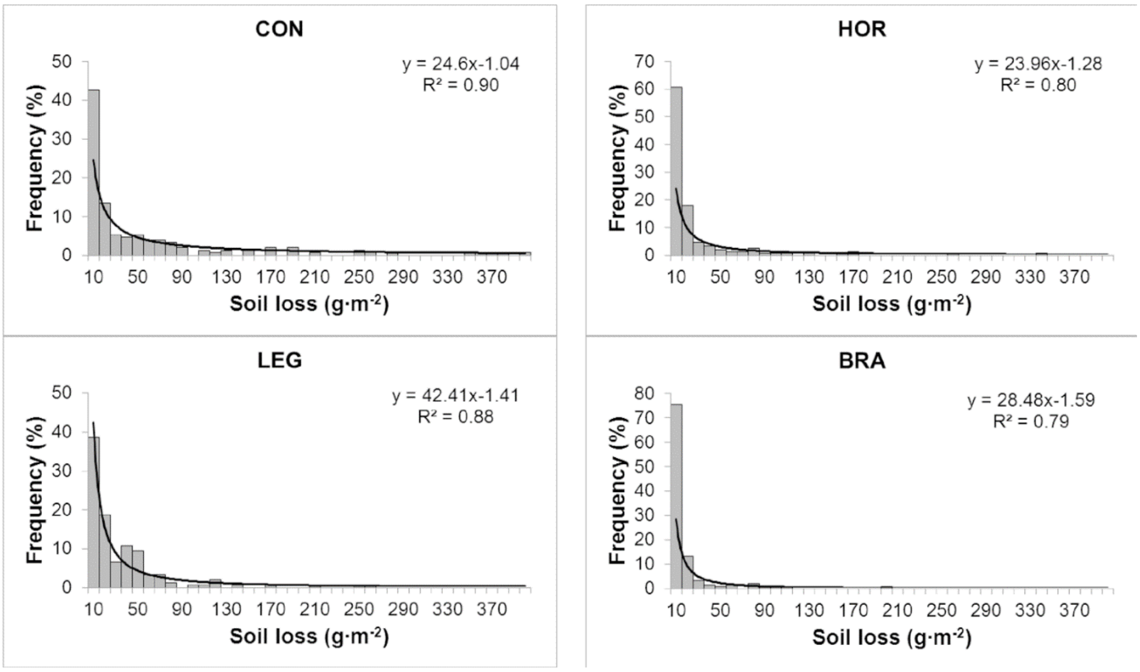

Figure 3. Relative frequency of soil loss per treatment (N=150).

We have used the classification of rainfall intensity reported by Porta *et al.*, (1999) to analyze the mobilized sediments. Less than 2% of total rainfall events were light (<2 $mm \cdot h^{-1}$), 86% were moderate (2-20 $mm \cdot h^{-1}$), 12% heavy (20-50 $mm \cdot h^{-1}$), and we did not record any event very heavy (50-90 $mm \cdot h^{-1}$) nor torrential (>90 $mm \cdot h^{-1}$). In the Centre of Spain the greatest proportion of rainfall events are moderate. In this region, during the study period, we have not recorded any event over 50 $mm \cdot h^{-1}$ although these events are not considered infrequent (García-Díaz *et al.*, 2015). In 2007 our team recorded a single event (P=43 mm, I=55 $mm \cdot h^{-1}$) which produced a soil loss of 93.47 $t \cdot ha^{-1}$ (Bienes *et al.*, 2012).

Only 6 out of 50 rainfall recorded events were heavy, producing from 16 to 28% of total mobilized sediments, depending on the treatment (Table 4). Considering treatments, both CON and HOR yielded more sediment per event in heavy rainfall events than with moderate. This difference did not appear with BRA, which had low rates of soil loss in both cases, nor in LEG with high rates.

Soils under moderate rainfall events were best protected with BRA, controlling almost all the sediment delivery. The worst were LEG and CON, while HOR was in an intermediate place. Under high intensity events, BRA was still the best cover protecting soil and CON was the worst.

Table 4. Number of rainfall events (N); cumulative soil loss; percentage of soil loss regarding the total soil loss within the treatment; mean and SD of soil loss per event for each management and rainfall intensity (soft: <2 $mm \cdot h^{-1}$, moderate: 2-20 $mm \cdot h^{-1}$ or heavy : 20-50 $mm \cdot h^{-1}$).

Treatment	Rainfall intensity	N	Cumulative soil loss ($g \cdot m^{-2}$)	Percentage of soil loss (%)	Mean and SD of soil loss per event ($g \cdot m^{-2}$)
CON	Soft	1	35.65	1.38	35.65
	Moderate	43	1835.58	71.06	42.69±38.68 a A
	Heavy	6	712.23	27.56	118.71±102.64 b A
HOR	Soft	1	4.19	0.40	4.19
	Moderate	43	764.55	72.41	17.78±22.89 a B
	Heavy	6	287.49	27.19	47.92±44.70 b AB
LEG	Soft	1	28.54	1.84	28.54
	Moderate	43	1191.71	76.69	27.71±30.30 a A
	Heavy	6	334.60	21.47	55.77±43.55 a AB
BRA	Soft	1	0.01	0.01	0.01
	Moderate	43	393.56	83.56	9.15±13.82 a C
	Heavy	6	77.86	16.53	12.98±15.32 a B

Different lowercase letters in each column mean differences between treatments within the same rainfall intensity. Different uppercase letters in each column mean differences in rainfall intensity within each treatment at p<0.05.

We have correlated soil loss with the characteristics of the rainfall event and the percentage of coverage in the microplots (Table 5). High correlations ($p<0.01$) were found between all the analysed variables and soil loss. The best correlated variable was the coverage, with a negative relationship, as Dunjó *et al.*, (2004) found with the same degree. I_{15}, I and P were other factors that correlated very well with soil loss. We also found high correlations among climatic variables.

Table 5. Correlation matrix of soil loss, coverage, rainfall depth (P), maximum 15-minute rainfall intensitiy (I_{15}), maximum 30-minute rainfall intensity (I_{30}), maximum hourly rainfall intensity (I), kinetic energy (KE) and rainfall erosivity (R).

	Soil loss	Coverage	P	I_{15}	I_{30}	I	KE
Coverage	-0.478**						
P	0.251**	0.009					
I_{15}	0.274**	-0.018	0.427**				
I_{30}	0.183**	-0.018	0.416**	0.809**			
I	0.261**	-0.047	0.422**	0.824**	0.727**		
KE	0.211**	0.034	0.816**	0.448**	0.445**	0.471**	
R	0.233**	0.014	0.678**	0.634**	0.711**	0.601**	0.827**
** p<0.01							

A regression analyses was performed employing the different variables studied and the transformed soil loss data. We obtained a model with a R^2 coefficient of 0.293 (F=42.178, df=2, p<0.001). Only 2 out of the 7 studied variables had significance into the model: coverage, being the most important predictor with a weight of 0.76; and kinetic energy with 0.24. The rest of climatic variables did not contribute to explain the dependent variable.

$$Soil\ loss = e^{2{,}865-0{,}023*Covered+0{,}141*KE} - 1$$

3.2.1. Soil coverage

One of the main effects of vegetation on soil protection is due the coverage avoiding the direct impact of raindrop on soil and stopping runoff. As can be seen in Figure 4 a good adjustment with a logarithmic equation between soil loss and ten categories of coverage was found (R^2=0.81). The important effect of protecting the soil against erosion is crucial in low percentages of coverage. If conservation tillage (with at least 35% of soil covered) was applied, soil loss would reduce 55%. If the coverage raised 55%, the reduction would reach 70%. Increasing soil coverage beyond 55% is very difficult in gypsiferous soils under semi-arid climate, and the effect on soil loss reduction is not as big as in low coverage. Furthermore, the effort and economic investments needed to achieve higher covers seems not justify the soil loss reduction.

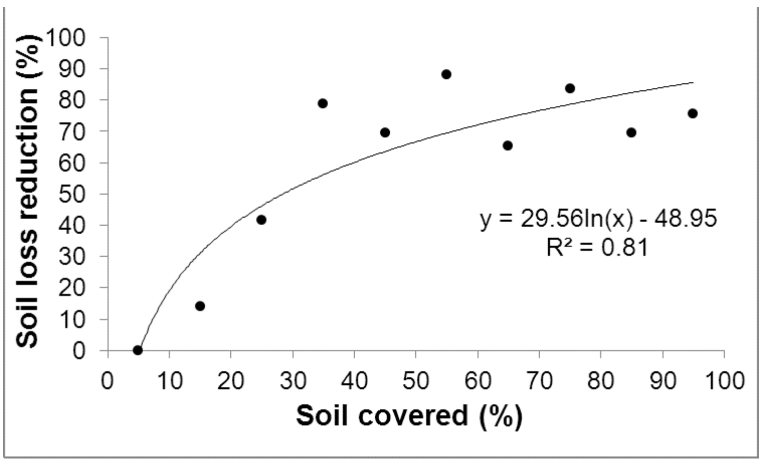

Figure 4. Soil loss reduction versus soil covered.

In Table 6 soil loss is showed within 3 coverage groups –independent on treatments-: low (0-20%), medium (20-40 %) and suitable (>40%) for the three levels of intensity.

Table 6. Mean and SD of soil loss per event, number of cases in brackets (N). Soil coverage: low (0-20%), medium (20-40 %) and suitable (>40%); maximum hourly rainfall intensity: soft= <2 $mm\cdot h^{-1}$, moderate= 2-20 $mm\cdot h^{-1}$ and heavy= >20 $mm\cdot h^{-1}$.

Soil loss ($g\cdot m^{-2}$)		Rainfall intensity		
		Soft	Moderate	Heavy
Soil covered	Low	22.79±16.50 (3) a	34.85±36.07 (89) aA	81.81±80.82 (14) bA
	Medium	n.d.	15.58±16.17 (36) aB	37.32±25.23 (6) bAB
	Suitable	0.01 (1)	11.14±16.90 (47) aB	10.73±15.21 (4) aB

n.d.: no data

Different lowercase letters in each row mean differences between rainfall intensity. Different uppercase letters in each column mean differences between coverages at $p<0.05$.

Light intensities of rainfall only produced soil loss if the coverage was less than 20%. If the coverage was scarce or medium, heavy events generated significantly higher soil loss than light or moderate events. Once the coverage overtaken 40%, the intensity of rainfall did not affect soil loss due the protective effect of plant cover. In these cases, we did not find differences between rain intensities.

Moderate rainfall events produced more sediments with a scarce coverage compared with plots having coverage above 20%, similarly to the results found by Marques *et al.*, (2008) with coverages above 60%. Under heavy rainfall events the intermediate class of coverage did not provide an appropriate soil protection. At least 40% of soil should be covered by vegetation to control sediment delivery.

3.2.2. Kinetic energy

Kinetic energy was the other relevant variable regarding soil loss in the regression model. In Figure 5 a linear adjustment was found between cumulative soil loss and cumulative KE per treatment. A high correlation was found in every case (R^2>0.93) with a higher slope in CON treatment, afterward LEG and HOR, and BRA had the smallest one, that means the lowest soil loss rate.

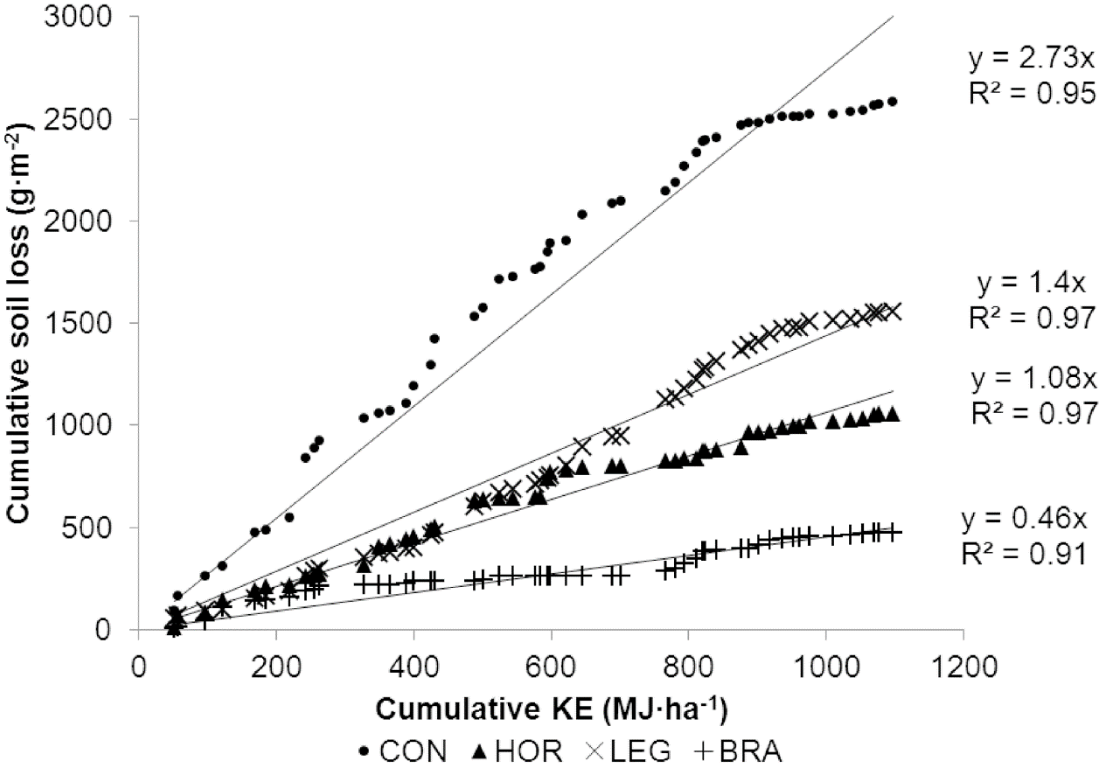

Figure 5. Linear regression between cumulative KE and cumulative soil loss for the different treatments.

For gypsiferous soils under semi-arid climate keeping soil coverage above 40% in spring and autumn is compulsory to protect the soil against erosion; such prevention measures must be adapted to the particular climatic conditions (Fleskens and Stroosnijder, 2007).

3.3. SOC content and texture of sediments

Soil texture of Ap horizon and eroded sediments is shown in Figure 6. The eroded sediments correspond to the 10 selected samples. Sediments removed and transported by erosion increase percentage of fine fractions compared to the upper horizon (Ap) of the soils of origin. There is a significant increase of 50% in clay content (Table 7), and a decrease in sand fraction of sediments. Changes in particle size distribution are frequently mentioned in the literature, Martínez-Mena *et al.*, (2002) found less sand (>50 μm) in sediments eroded after rain events of high or medium intensity. Erosion is a selective process as Martínez-Mena *et al.*, (2001) described. Different authors find different particle size enrichment, e.g., Martínez-Mena *et al.*, (2002) and Pieri *et al.*, (2009) describe silt enrichment (2-20 μm), while in this study the main change was found for clay fractions.

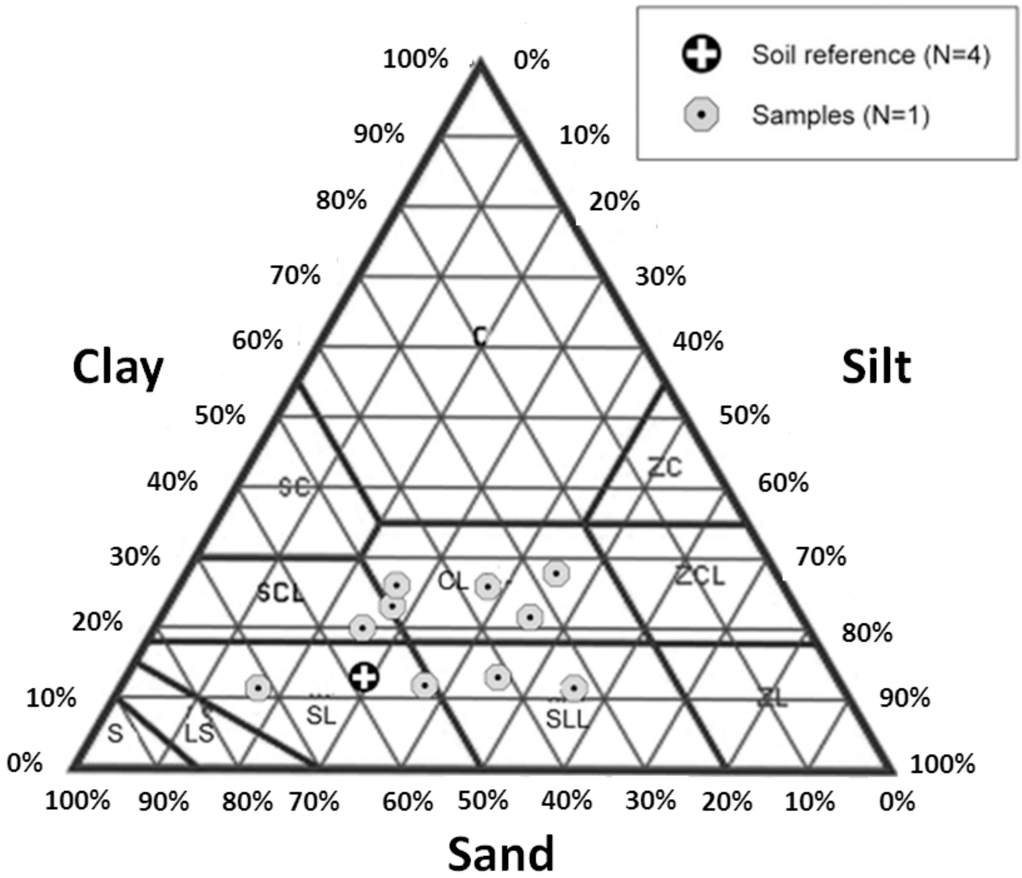

Figure 6. ISSS textural diagram. The white cross notes the original texture of soil. The grey circles correspond to the 10 sampled sediments.

SOC was 2.5 times higher in sediments than in original soil (Table 7). Organic carbon enrichment of sediments has been described in erosion studies (Marques *et al.*, 2008; Martínez-Mena *et al.*, 2012; Márquez-García *et al.*, 2013). On average, 1.51% of SOC was lost in eroded sediments, being this rate similar to the one found by Martínez-Mena *et al.*, (2008) in an olive grove in the SE Spain.

Table 7. Comparison between original soil of reference and sediment samples. Soil analyses result as the average of 4 sub-samples; sediment texture analyses represent the average of 10 samples and SOC sediment analyses represent the average of 8 samples Statistical significance of differences is described by the p-ANOVA.

	Reference soil (Ap)	Samples	p-value
Sand (2000-20 µm) (%)	57.9±11.5	43.8±13.0	0.084
Silt (20-2 µm) (%)	29.2±14.1	36.6±12.1	0.343
Clay (<2µm) (%)	12.2±2.4	19.6±6.4	0.048
Silt+Clay (<20µm) (%)	41.4±12.4	56.2±13.0	0.076
SOC (%)	0.62±0.08	1.51±0.38	0.001

The relationship between SOC, texture and rainfall events was studied by means of their degree of correlation (Table 8). Significant relationships were found for SOC and both silt and clay+silt fractions ($p<0.05$), therefore, fine fractions and SOC are linked. Clay and SOC form organo-mineral associations by electrical bonds, while silts and particulate organic matter have similar particle size and experience similar dynamics (Porta *et al.*, 1999). Particularly rainfall events having higher intensity (I_{30} or I) showed higher SOC loss ($p<0.10$). However, in this study no extreme events were recorded as the maximum rainfall intensity was below 50 mm h^{-1}; arguably sand particles can be dragged by high intensity showers. Martínez-Mena *et al.*, (2001) studied soil erosion at basin scale and found that sand particles (63-900 µm) were transported by high intensity events. In this study, coarse sand (2000-200 µm) did not establish correlations with rainfall intensity. On the contrary, fine particles (<20 µm) were correlated to rainfall intensity. Soil microaggregates are included in this kind or size particles, having less than 20 µm, and can be considered as an effective sediment size in soil mobilization studies (Martínez-Mena *et al.*, 2002)

As expected, SOC mobilization was also related to rainfall intensity, in this case with I ($p<0.10$) (Table 8); this relationship has been described in olive groves by Martínez-Mena *et al.*, (2008). Considering the basin scale, this process lead to soil fertility decline on-site, and water pollution off-site, due to rich SOC suspended sediments that are transported by runoff (Pieri *et al.*, 2009).

Table 8. Statistical correlations established between soil organic carbon (SOC), soil textural classes (Sand, Silt, Clay and Silt+Clay), Rainfall depth (P), maximum intensity in 15 minutes (I_{15}), maximum intensity in 30 minutes (I_{30}), maximum intensity in 1 hour (I), Kinetic Energy (KE), and erosivity (R Factor).

	SOC	Sand (2000-20 µm)	Silt (20-2 µm)	Clay (<2 µm)	Silt+Clay (<20 µm)
SOC		-0.700*	0.750*	0.200	0.700*
P	-0.024	-0.055	-0.297	0.527	0.055
I_{15}	0.602	-0.762*	0.470	0.652*	0.762*
I_{30}	0.635†	-0.796**	0.620*	0.450	0.796**
I	0.627†	-0.710*	0.440	0.599†	0.710*
Ec	0.190	-0.127	-0.212	0.552†	0.127
R	0.262	-0.491	0.139	0.636*	0.491

** p<0.01; * p<0.05; † p<0.10

In Table 9 results are grouped according to the intensity of events. We considered that moderate events have intensities less than 20 mm·h^{-1}, and higher intensity events are comprised between 20 and 50 mm·h^{-1}. There were no differences in sediment yield particle size for this grouping. This may be the result of soil crust produced after rainfall events and further mobilization of clay particles that obstruct porosity and increase bulk density in the few mm of topsoil.

Table 9. Mean and SD of different textural fractions and SOC according to different groups of rainfall intensity, moderate $2<I<20$ mm·h^{-1} and heavy intensity $20<I<50$ mm·h^{-1}.

	Rainfall event		
	Moderate (N=5[1])	Heavy (N=5)	p-value
P (mm)	33.8±11.8	49.5±21.8	
I_{15} (mm·h^{-1})	6.5±1.7	21.0±10.3	
I_{30} (mm·h^{-1})	5.7±1.5	13.3±6.5	
I (mm·h^{-1})	7.9±2.0	29.3±12.3	
KE (MJ·ha^{-1})	4.8±1.7	8.5±3.5	
R (MJ·mm·ha^{-1}·h^{-1})	15.0±5.3	68.5±42.7	
Sand (2000-20 μm) (%)	49.9±14.3	37.7±9.2	0.15
Silt (20-2 μm) (%)	33.2±12.3	39.9±12.3	0.41
Clay (<2 μm) (%)	16.9±6.2	22.4±6.0	0.19
Silt+Clay (<20 μm) (%)	50.1±14.3	62.3±9.2	0.15
SOC (%)	1.3±0.4	1.6±0.4	0.31

[1]N=5, except for SOC that was N=3

3.4. Cover crop adoption in the region

The number of farmers participating in the survey represents the 10% of farmers of this south east county of Madrid. They are in average 54±14 years old (N=120); many of them (52%) have other activities to obtain their incomes. Seventy percent of respondents grow olive trees. They often declare not having received any education or training with regard to soils (78 % of them), including basic school topics. Most farmers (82%) continue the family tradition but only 54% declare their willingness to transmit their way of living to their sons. Nearly all of them (94%) receive subsidies to support farming activities. However, the number of aids related to soil conservation or ecological practices are below 16%. Soil management is based mainly on tradition, literally they practice "what has been always made", the second reason for selecting a particular management practice is leaded by economic profit, the third reason they mention to select management practices is related to product quality, finally at the fourth place environmental reasons are noted.

Considering soil conservation problems, in order of importance farmers are concerned about steep slopes, waterlogging of soils, low fertility, erosion, poor water holding capacity, soil organic matter depletion, compaction, pollution, salinization, alkalinity and acidity. They consider that they can contribute to solve soil problems (84%), especially by increasing SOC, fertilizers or pesticides (57%), improving their way of ploughing (21%), and carrying out land levelling works (12%) . Only 9% of farmers think that they can improve soil conditions by the adoption of more sustainable land management practices. They declare that they would need better training and institutional aids, as a following ranking importance they mention the need of better technology; similarly, environmental awareness is the last concern regarding needs for changing soil problems.

The sources of information for their professional activities are mainly regional extension services (22%). They also consult their neighbors and acquaintances (19%) and internet (14%). Minor sources are commercial agricultural suppliers (11%), farmers associations (15%). Few farmers (<4%) use specialized publications, newspapers or university professionals if they are looking for advice.

Agricultural soil degradation is not obvious for farmers and therefore change their management practices is not a priority for them. Only 5 out of the 84 olive growers of the survey used cover crops in their lands, and they do it for economic reasons, not for environmental concerns. Two farmers describe how they let grow the spontaneous vegetation in order to save labour and fuel costs; they use herbicides in spring to avoid water competition but they do not consider such practice as cover crops. Moreover, they mention a social disapproval towards those who "do not work the soil"; they frequently mention that let growing vegetation in the olive groves "is of lazy farmers."

In this context, the work of extension agents and institutions responsible for education and training is considered important to show that the use of cover crops does not affect dramatically olive production (data publication under review) and is environmentally positive.

4. CONCLUSIONS

Gypsiferous soils are vulnerable to water erosion processes if they are not protected by vegetation, even under moderate intensity rainfalls. This study shows that soil loss is correlated to vegetation scarcity and rainfall intensity. The upper limit of rainfall intensity was 50 $mm \cdot h^{-1}$ in this period. Spring and autumn concentrate higher intensity rainfalls, therefore soil loss is also higher in that seasons. Farmers should adopt particular soil cover practices in those periods.

Permanent cover crops (*Brachypodium distachyon*) in olive groves demonstrated their efficiency to prevent water erosion; after one year, the establishment of this cover is enough to obtain sediment yield that can be considered tolerable. Annual cover crops (*Hordeum vulgare* and *Vicia ervilia*) were also efficient in spring but they needed time to be established; unlikely *Onobrychis viciifolia* was not suitable for this area. During autumn and winter annual cover crops were not completely established and soil loss was important.

This soil under this climate can be easily covered by 40-50% of vegetation, under these circumstances soil loss can be reduced by 60-70%. Such soil coverage around 50% in spring and autumn can be achieved after 2 or 3 years, but only in permanent cover crop treatments.

This study demonstrates a selective transport of particle size due to erosion, there was an increase of 50% of clay fraction in eroded sediments, considering both the moderate or high rainfalls taken place in this period.

Organic carbon is lost with fine soil fractions as sediments are enriched in SOC (mean content 1.5%) having 2.5 times more content than the soil of origin. This fact aggravates the current state of organic matter depletion characteristic of these poor and shallow soils. Farmers have to be conscious of the importance of vegetation cover especially in autumn and spring. Cover crops in olive groves are rare in the region because farmers are not willing to change traditional management practices. Their practices are driven by economic reasons. Possible changes towards cover crops would be possible if there was an economic profit, not only an environmental benefit.

5. ACKNOWLEDGEMENTS

“This work was supported by the Regional Agri-Environmental Research Institute IMIDRA under Grant FP12-CVO.”

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11

Farmers and soil science criteria assessing plots quality in Las Vegas agrarian district (SE Madrid, Spain)

FARMERS AND SOIL SCIENCE CRITERIA ASSESSING PLOTS QUALITY IN LAS VEGAS AGRARIAN DISTRICT (SE MADRID, SPAIN)

(Manuscrito en preparación para su envío a *Agriculture, Ecosystems and Environment)*

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KEYWORDS: Desertification, farmer's perception, hybrid knowledge, Mediterranean region, soil quality assessment, tacit knowledge.

1. INTRODUCTION

The relevance of traditional knowledge in managing natural resources and particularly agrarian ecosystems is widely recognized (Agrawal, 1995; Lima et al., 2011; Mairura et al., 2008; Romig et al., 1995; Ryder, 2003; Subedi et al., 2009; Thrupp, 1989). Land users' knowledge is even described as the 'fourth factor of production' because of the widely differing knowledge, skills and aptitudes that farmers need for producing food (Winter, 1997**.** Land users hold an holistic knowledge of agrarian ecosystems (Desbiez et al., 2004; Lima et al., 2011). They combine information about soils, seeds, weather or water with practical information related to markets, labour, machinery, investment, local traditions and even social recognition and prestige (Sillitoe, 1998).

In the case of soil, a key factor of production, whilst it is accepted that farmers' knowledge of land management is important, very little is known about it (Ingram, 2008). Local knowledge is not sufficiently integrated in formal scientific literature (Desbiez et al., 2004; Mairura et al., 2008), this gap being particularly relevant when dealing with problems of land degradation and desertification (Stringer and Reed, 2006).

Due to the local specificity and richness of the traditional knowledge of each region, the United Nations Conventions to Combat Desertification as well as other international institutions formally recognize the key role of land users in order to fight land degradation and to warrant food security (CBD, 2004; FAO, 2009; UNCCD, 2005).

Consequently these international institutions and numerous authors propose land users' involvement to consolidate what can be defined as "hybrid knowledge" (Kloppenburg, 2010; Murdoch and Clark, 1994; Stringer and Reed, 2006; UNCCD, 2015; Winklerprins, 1999). The hybrid knowledge is built with two key ingredients: scientific learning based in the study of biophysical, economic and social factors affecting land degradation (know-why); and the traditional perceptions and experiences of local populations rooted on empirical learning of watching and doing (know-how) (Lundvall and Johnson, 1994).

The soil hybrid knowledge represents a step forward with respect to that developed by soil sciences (Barbero-Sierra et al., 2015; Escadafal et al., 2015). Its progress requires the contribution of multiple sources of knowledge and consequently the enrolling of different stakeholder (researchers, land managers, decision makers) (Reed et al., 2013).

Ethnopedology is an innovative, hybrid discipline nurtured from natural and social sciences that documents and studies the local approaches to soil perception, classification, appraisal, use and management (Barrera-Bassols and Zinck, 2003; Barrera-Bassols et al., 2006; Sillitoe, 1998; Winklerprins and Sandor, 2003). It represents a consistent source of methods and case studies aimed at connecting scientific and traditional knowledge.

Ethnopedology approaches soil and land from three perspectives: cognitive domains or knowledge (Corpus); management of land resources (Praxis); and the objects of symbolic meanings and values (Kosmos) (Barrera-Bassols and Zinck, 2003). Ethnopedological works have been classified in three main domains: ethnographical, comparative and integrated (Barrera-Bassols and Zinck, 2003; Winklerprins, 1999).

The present study could be included under the comparative domain, focusing on the Corpus dimension of farmers' knowledge in Las Vegas (SE Madrid). Our hypothesis is that farmers and scientists' knowledge of soil share a common base but also have specific ways to interpret and assess agricultural plot qualities derived from a predominant know-why versus know-how approaches. We explore these common and specific grounds, analyze differences in farmers' knowledge and assess the factors that influence these differences.

2. MATERIALS AND METHODS

2.1 Study area

Las Vegas agricultural district (southeast of Comunidad de Madrid, Spain; see Figure 1), includes 23 municipalities with a total area of 1379 km^2 and a population of 157,528 inhabitants (Instituto de Estadística de la Comunidad de Madrid, 2014).

Figure 1. Las Vegas agricultural district, located at the South East of Comunidad de Madrid (Spain).

It is a semiarid territory (average yearly temperature 15ºC and 340 mm rainfall; AEMET, 2015; Botey Fullat et al., 2013) with an altitudinal range from 489 to 761 m.a.s.l. The district is crossed by the Tajo (Tagus) River and two of its tributaries (Tajuña and Jarama) that have carved the Miocene (Tertiary) sedimentary plateau, resulting in a rolling landscape of generally moderate slopes.

The geological and geomorphological traits have combined to create a complex edaphic mosaic with a diversity of soil types (Xerochrept and Xerothent according to the USDA-NRCS soil classification) (Fernández González et al., 2013). The quaternary soils on the rivers' terraces offer the most productive conditions for horticultural crops and maize based on surface irrigation. Poor and stony soils are occupied with olive groves and vineyards, whereas rain-fed cereals, leguminous and other annual crops thrive on intermediate quality soils. A few pockets of natural secondary and planted forests dot the landscape occupying the most marginal land. The area is subject to desertification processes compounded by soil degradation and erosion (Bienes Allas et al. 2001).

2.2 Data collection

An initial survey of 120 full or part-time farmers to assess their knowledge and perceptions about soil conservation and management was developed. Of the full-time farmers from this preliminary sample, 31 were randomly selected. They were asked for their agreement to visit their farms and to respond to an in-depth semistructured interview.

Before the visits, farmers were requested to identify a good and a bad plot in the farm in order to collect soil samples from them. The interview focussed on the reasons for selecting those plots, farmer's caracterization and quality description of their soils, and soil and water management practices implemented in both plots. They were also asked about 11 edaphic characteristics that may afect their fields.

In the farm visits, samples were collected, corresponding to a pair of good plot-bad plot for each farmer. An incident during the visit to one of the farms only allowed us to take samples from one plot. In each plot 1 kg of surface soil (0-20 cm deep) was collected from 5 to 8 sub-samples randomly selected within a 10m radius, mixing them in a single bag. Farm visits were carried out from July 2014 to March 2015, each visit lasting between one and two days.

The soil samples were dried. For each of them we measured Soil texture (Robinson pipete and Bouyoucos densimeter methods) (Bouyoucos, 1962; MAPA, 1994); Soil Organic Carbon (SOC) (Walkley and Black, 1934); Potentially Mineralizable Nitrogen (PMN) (Bremner and Edwards, 1965; Keeney and Nelson, 1982) ; pH (1:2-5 (v/v)) (MAPA, 1994); electrical conductivity (EC) (1:5 (v/v)) (MAPA, 1994); bulk density (BD) (Hg method) (Johnston, 1945) and aggregate stability (Counting Number of Drops method) (Imeson and Vis, 1984). Each sample had a duplicated analysis that was subsequently averaged in order to obtain its edaphic parameters for 61 plots.

2.3 Data analysis

The information collected through the 31 interviews was codified into nominal, ordinal and quantitative variables. Since farmers only identified and assessed the relevance of those soil factors about which they were knowledgeable, the number of factors mentioned by each farmer can be used as a proxy for the degree of soil-related knowledge. This information was transformed into a continuous variable ranging from 0 to 1.

The reasons to identify their best and worst plots in the farm were codified and based on that farmers were categorized in two groups: “Soil farmers” are those who exclusively employed soil features and yield productivity to choose their good-bad plots. “Land farmers” combine soil and productivity criteria with other factors such as quality of the yield, access, size and distance of the plot, workability, water availability, pests, or even emotional reasons.

We constructed a edaphic quality index adding two terms, one containing the pedotransfer function for water availability (based on SOC, texture and bulk density, Pachepsky and Van Genuchten, 2006) and the other containing the aggregate stability, pH, EC and PMN. This index was subsequently transformed to a 0 to 1 scale.

In the pair of plots selected by each farmer, the quality ranking provided by the edaphic quality index was compared with the plot quality as assessed by the farmer. We created a variable that records the agreement or disagreement between the laboratory and farmer's plot quality ranking.

Descriptive statistics, Pearson correlation, parametric (ANOVA) and non-parametric (Mann-Whitney, Kruskal-Wallis, X^2) tests, regression models (Linear Generalized Model and LOGIT), and multivariate (Categorical principal components) analysis were conducted using SPSS v.22 (IBM Corporation, 2012).

3. RESULTS

3.1 Farmer and soil profiles

Our sample was composed of 30 male and one female full-time farming respondents; females were underrepresented with regards the official female agricultural population statistics of the district (INE, 2002). This is due to the fact that women working in agriculture tend to be part-time farmers with an off-farm main income generating activity. Average age was 52 years (s.d.=11.7) on line with the average farmers' age in the district, reflecting the aging situation of farmers in the region. Primary education (32%) was the most common category, followed by secondary education (26%); 19% of respondents had a professional training degree, while 23% held a university degree. Education was not related to age (Kruskal-Wallis p=0.12), although it is worth noting that while primary education was more common in older farmers, a number of these had university degrees.

The soil samples analyzed for the 61 agricultural plots reflect the variety of soil conditions in Las Vegas district. Table 1 summarizes the edaphic parameters analyzed in the laboratory, differentiating between good and bad quality plots as identified by farmers. Only organic matter and clay have statistically significant differences between the two plot quality groups at $p<0.10$.

		Mean	SD	Minimum	Maximum	ANOVA	
						F	Sig.
ORGANIC MATTER	GOOD	1.55	0.69	0.00	3.47	3.006	.088
	BAD	1.25	0.68	0.00	2.51		
BULK DENSITY	GOOD	1.57	0.12	1.28	1.78	.706	.404
	BAD	1.54	0.17	1.15	1.99		
AGGREGATE STABILITY	GOOD	28.44	10.86	10.32	51.16	.045	.833
	BAD	27.80	12.27	7.76	74.00		
pH	GOOD	8.00	0.28	7.26	8.40	2.783	.101
	BAD	8.12	0.30	7.64	9.21		
ELECTRIC CONDUCTIVITY	GOOD	293.09	431.00	87.20	2354.00	2.750	.103
	BAD	650.95	1103.04	78.55	5230.00		
NITROGEN	GOOD	21.28	16.39	1.91	58.57	.074	.787
	BAD	23.15	34.15	1.61	177.20		
WATER AVAILABILITY	GOOD	9.98	3.14	7.23	18.91	.653	.422
	BAD	9.33	3.07	4.96	17.69		
CLAY	GOOD	21.16	6.76	3.12	32.20	3.390	.071
	BAD	18.02	6.58	2.85	30.50		
SILT	GOOD	24.06	20.99	9.33	83.05	.138	.712
	BAD	22.23	17.41	1.61	76.45		
SAND	GOOD	54.78	19.02	3.50	71.24	1.183	.281
	BAD	59.76	16.65	13.30	84.55		

Table 1. ANOVA tests for edaphic parameters of good and bad plot samples defined by farmers.

However, soils from plots considered by farmers as having better quality show a significantly higher edaphic quality index than those from less quality plots (Mann-Whitney U=323.00; p=0.041).

3.2. Factors influencing farmer's soil knowledge

The average soil knowledge index was 0.63 (s.d.=0.24), with a minimum knowledge of 5 soil characteristics and a maximum of 11. The most commonly known features were slope, soil compaction, water retention. The least mentioned were acidity, alkalinity and salinity. Soil knowledge was not related to age (Pearson r=0.174; p=0.35), but it was related to level of education (Kruskal-Wallis p=0.045).

Twenty one farmers were identified as having a land vision and 10 a soil vision. The classification of farmers in either of these categories was not related to age (Mann-Whitney U=88.00; P=0.47) or level of education (Mann-Whitney U=99.50; p=0.81). However, farmers with a land vision have a significantly higher soil knowledge than those with a soil vision (Mann-Whitney U=59.50; p=0.048).

We used a Univariate General Linear Model to assess the combined effects of education (entered as an ordinal variable) and soil/land vision on soil knowledge (Table 2).

Dependent Variable: SOIL KNOWLEDGE

Parameter	B	Std. Error	t	Sig.
Intercept	.328	.105	3.128	.004
EDUCATION	.086	.033	2.564	.016
LAND VISION	.151	.082	1.842	.076
SOIL VISION	0[a]	.	.	.

R Squared=0.254; Adjusted R Squared=0.201
a. This parameter is set to zero because it is redundant.

Table 2. Univariate General Linear Model of Soil knowledge (response variable) with farmer's level of education and vision (predictors).

The model (corrected R squared= 0.20; p<0.01) confirms the positive effect of higher level of education and having an integrated land vision on soil knowledge.

3.3. Farmer and laboratory soil assessment: agreements and disagreements

In 21 cases the order of the farmer's quality assessment for the two plots in the pair coincides with the quality ranking provided by the edaphic index. For the case were we could only get samples from one plot of land, this was classified as bad quality by the farmer, and its edaphic quality index (0.22) was below the average index for the bad quality samples (0.31). Consequently we also considered this case as coinciding. In the remaining 9 cases there was a disagreement between the quality order given by the farmer and that based on the edaphic index. Therefore, an agreement between farmer and edaphic quality index criteria to classify a soil as better or worse than another in a pair of plots is 2.44 times more likely than a disagreement, the difference being statistically significant (X^2=5.452; p=0.020).

There were no statistically significant differences in age (Mann-Whitney U=89.00; p=0.632) and education level (Mann-Whitney U=95.00; p=0.857) between the cases where the farmer and laboratory criteria agreed and those that did not. The cases of agreement had a higher soil knowledge (Mann-Whitney U=47.50; p=0.021), and tended to have a land vision (X^2=3.150; p=0.076). The difference in soil quality index between the pairs of cases where there was agreement tended to be larger than in the cases of disagreement (Mann-Whitney U=61.00; p=0.098).

We used a binary LOGIT regression to predict the agreement between farmers and laboratory edaphic quality assessments using the three variables that showed statistically significant differences at p<0.10.

Dependent variable: FARMER-LABORATORY AGREEMENT
Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)
VISION	1.490	1.011	2.174	1	.140	4.44
EI_DIFERENCES	7.589	4.325	3.079	1	.079	1,976.66
SOIL KNOWLEDGE	3.783	2.401	2.481	1	.115	43.93
Constant	-3.322	1.726	3.702	1	.054	.04

Table 3. Binary Logistic Regression model of Agreement/Disagreement (Response variable) with Differences in edaphic index in the good-bad plot pair, farmer's vision and soil knowledge

The Nagelkerke R Squared for the model is 0.381, with a sensitivity index (percentage of correct classifications of agreements) of 91%, and 81% overall correct classifications. The model suggests that the most determining factor is the absolute difference is edaphic quality index between the samples of the two plots being compared, followed by the degree of soil knowledge and farmer's vision. Higher differences in edaphic index between the plots of a given pair, higher soil knowledge and a land vision increase the likelihood of agreement between farmers and laboratory.

Finally, we use a Categorical Principal Components Analysis to explore the combined relationship between the above variables taken together (Figure 2).

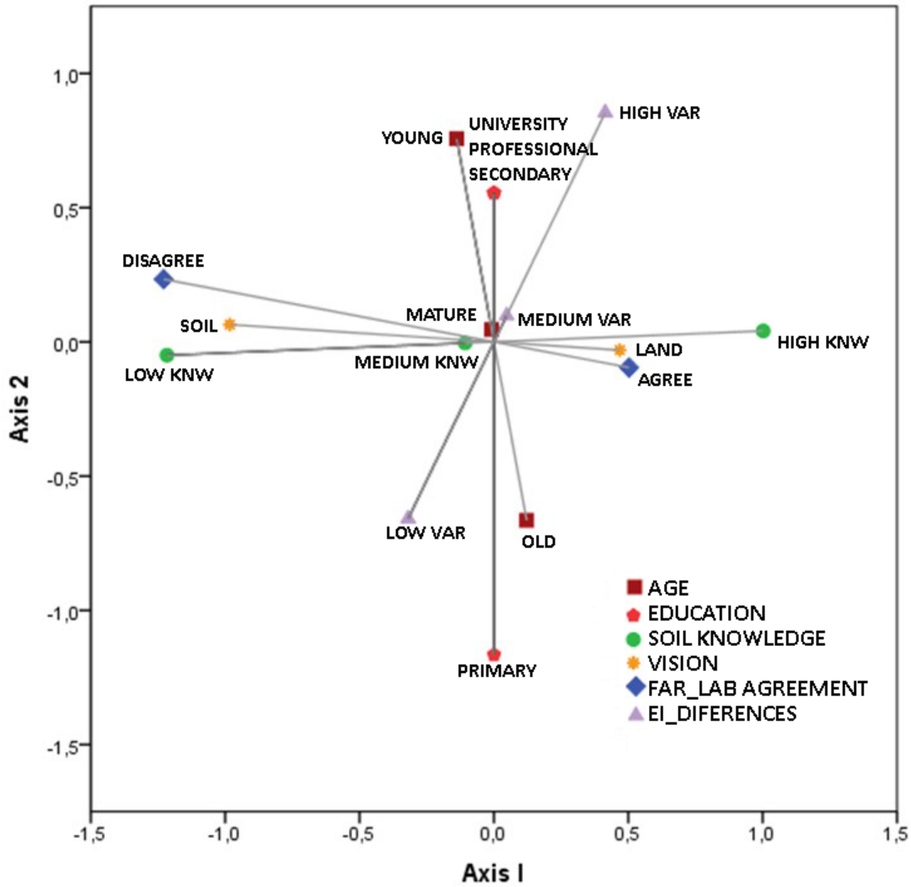

Figure 2. Categorical Principal Components Analysis of farmer age, level of education, soil knowledge, vision, farmer-laboratory agreement and edaphic index differences in the pair of plots. Axis 1 = 28% variance; axis 2 = 21% variance.

The right side of axis 1 represents a high soil knowledge, land vision, agreement between farmer and laboratory soil quality criteria and a large difference in edaphic quality index between the pair of plots of a given farm. The left side places together low knowledge, soil vision, farmer-laboratory disagreement and small differences in edaphic quality indices.

The second axis contrasts younger, more educated farmers that selected plots with large differences in edaphic indices (upper part) with older, less educated farmers that selected plots with small differences in edaphic quality indices (lower part).

4. DISCUSSION

Our sample of farmers shows a relatively high degree of knowledge about soil features. The most frequently known soil characteristics are those related to visual and other direct physical observations. The importance of these features that can be easily identified through senses has been observed in other studies (Ali, 2003; Desbiez et al., 2004; Mairura et al., 2008). Less frequently known are those soil chemical characteristics like salinity or pH that require specific laboratory analysis, a fact also reported in earlier studies (Ryder, 2003).

The level of formal education and an integrated land vision of their farm have a significant influence in the degree of knowledge. The effect of education has already been discussed in the literature (Ingram, 2008; Raymond et al., 2010), and is due to the synergy between a traditional knowledge learning that offers the foundation over which a scientific-technical knowledge and terminology is added. In this regard, it is worth mentioning the significant role played by the Madrid Regional Agricultural Extension Services in expanding this knowledge through specific training courses (Comunidad de Madrid, 2015).

The relationship between soil knowledge and a more comprehensive and holistic vision is complex and the causality path is difficult to assess. This relationship has been less frequently reported (Odendo et al., 2010), and is considered an important issue in rural development (Rahman, 2003).

The strong correspondence between farmers' plot pairs quality assessment and that obtained with a technically-based edaphic index suggests a broad common ground between traditional (know-how) and technical (know-why) knowledge (Ali, 2003; Reed, 2008; Stringer and Reed, 2006). While some soil indicators can only be measured through science and laboratory equipment, there are others that can also be accessed by farmers' empirical practice (Reed, 2008). The soil as an observable entity (know-why) and the soil as a production factor (know-how) share robust features that lead to a fundamentally compatible understanding (Romig et al., 1995).

On line with the above, while the edaphic quality index is significantly higher for the plots classified by farmers as good compared with those classified as bad, in the case of specific soil parameters these differences are statistically significant only for Organic Matter and Clay contents. These two parameters are easily recognizable by farmers. Organic Matter is a key factor in increasing crop yields (Diacono and Montemurro, 2010). Indeed, enriching the soil with manure and crop residues is one of the most common management practices conducted by farmers in the region. Moreover, a good level of Clay content improves the soil water retention capability (Hall et al., 1977), a major concern in a semiarid region where soil texture tends to be sandy or sandy-loamy (Bienes Allas et al., 2001). This is recorded in the traditional knowledge through local terms referring to soil colour ('rubiadal' – blondy; 'tierras rojas' – red soils, …) and level of compaction ('fuerte' – strong; 'flojo' - loose, …) of the soil.

Unsurprisingly, larger differences in edaphic quality index have a strong influence in the coincidence between farmer and technical criteria when assessing the quality of a pair of plots. When there are small differences in edaphic index between the plots of a given pair, the fine-grained, multi-parameters chemical analyses may lead to opposite conclusions than those obtained with a coarse, sensorially-based assessment.

A higher farmer's soil knowledge also increases the likelihood of agreement. This is to be expected since soil knowledge incorporates in various degrees technical knowledge (Ingram, 2008). A higher level of integration of technical knowledge leads to an increase in farmers' degree of knowledge making it more compatible with the scientific criteria of the edaphic index.

Interestingly, a land vision has a positive effect on agreement. This suggests that the broader, more holistic criteria of a land vision may help to bridge the gap between the know-why and the know-how, lending support to the pledge for more holistic approaches in facing land degradation problems (Desbiez et al., 2004; Lima et al., 2011).

5. CONCLUSION

Although built through different processes, farmers and scientists' knowledge about soils have a broad compatibility. They also have specific strengths and weaknesses. The local, holistic and empirically based knowledge of farmers allow them to manage their plots but has limitations when dealing with new, fast changing scenarios and the need to adapt to them. On the other hand, scientific knowledge, while based on reductionist approaches not always relevant for farmers' daily business decisions, are more suitable for modelling and offering alternatives in changing scenarios.

They need for a mutual recognition and increased sharing of understanding and expertise is a crucial ingredient in building paths towards a challenging future. More research and results extension to the farmers has to be coupled with science paying increasing recognition to farmers' Corpus, Kosmos and Praxis.

6. ACKNOWLEDGEMENTS

This work has been possible thanks to the generous collaboration of the interviewed farmers as well as the logistical support of Marina Fernández Sánz, José Manuel Martínez y Beatriz Salinas.

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PARTE III

Conclusiones y recomendaciones

12. Conclusiones y recomendaciones

“Manejo del suelo y desertificación: entre la ciencia y la praxis” se aproxima a la desertificación desde un enfoque de lo general a lo particular. En los capítulos centrales se discute sobre las peculiaridades del fenómeno de la desertificación en España (fenómeno *push-pull*), así como sobre la estructura de la ciencia en torno al tema tanto en la esfera mundial como en los casos concretos de España y Argentina. Tras la caracterización general del conocimiento científico se ha centrado la atención en la importancia de complementar la ciencia con el saber-hacer tradicional y las percepciones de los agricultores sobre la gestión sostenible de la tierra.

La aproximación al saber-hacer y creencias de los usuarios se focalizó en el área periurbana de la ciudad de Madrid, una zona especialmente interesante al ser un claro exponente del fenómeno *push-pull* de la desertificación, donde si bien la agricultura juega un papel marginal en términos económicos, no es así desde el punto de vista socio-ambiental.

Atendiendo a la lógica conceptual de esta tesis así como a su estructura como compilación de publicaciones científicas, en este último apartado se sintetizan las principales conclusiones del trabajo y se presentan algunas recomendaciones generales en materia de lucha contra la desertificación.

12.1. CONCLUSIONES

12.1.1. Principales motores de la desertificación en España

- Entre 1976 y 2009, España perdió más de 3,5 millones de hectáreas de tierras agrarias. En ese mismo período, el área forestal se ha incrementado en aproximadamente 2,85 millones de hectáreas debido a la regeneración natural, la aforestación o la reforestación de tierras agrícolas abandonadas. El medio millón de hectáreas restante, considerada como tierra no agrícola, se ha convertido en territorio disponible para la expansión urbanística y por tanto susceptible a ser irreversiblemente degradado.

- La transformación de tierras agrarias en urbanizables responde a una dinámica *push-pull*, definida principalmente por factores políticos (ej. PAC, incentivos fiscales para la adquisición de vivienda o la Ley 6/1998 sobre régimen del suelo y valoraciones) y socio-económicos (ej. pérdida de rentabilidad del sector agrario, precio de los suelos urbanos frente a los rurales, dinamismo del sector de la construcción durante el período de burbuja inmobiliaria, impacto del turismo, éxodo rural, etc.).

- A nivel internacional, el sector agrario se ha señalado como una de las principales actividades humanas causantes de desertificación. Sin embargo en España, en las últimas décadas, el sector inmobiliario ha jugado un papel más determinante en la degradación irreversible del suelo. La casuística española puede extrapolarse a países en desarrollo y económicamente desarrollados, en los que el proceso de urbanización está en plena expansión, por ello es un ejemplo ilustrativo a nivel europeo y mundial.

- La urbanización es un agente de desertificación activo y da lugar a escenarios irreversibles a diferencia de la agricultura que puede ser un agente activo o pasivo y desembocar en estadios reversibles o irreversibles dependiendo del tipo, intensidad y duración de la actividad agraria.

- La no diferenciación de los pesos específicos de los factores socioeconómicos y políticos frente a los agentes naturales es una de las debilidades de la Convención de Naciones Unidas de Lucha Contra la Desertificación.

12.1.2. La investigación científica, un elemento estratégico en la lucha contra la desertificación

- El conocimiento científico sobre la desertificación es escaso en comparación con la investigación generada respecto a otras cuestiones globales como el cambio climático o la pérdida de biodiversidad.

- La atmósfera de crisis socio-ambiental extrema, en la que se fraguó la Convención de Desertificación y que posteriormente se ha diluido, ha contribuido a la creencia de que la investigación respecto al tema también ha perdido importancia en el camino. Sin embargo la mayor parte del conocimiento científico relativo a la desertificación se ha publicado a nivel internacional en los últimos quince años.

- China es el país sobre el que más se ha investigado y en el que más investigadores trabajan sobre desertificación. Tan sólo un puesto por detrás aparece España y en quinta posición Argentina, como países en los que los investigadores localizan el estudio de la desertificación. La importancia de España y Argentina en el estudio de la desertificación se debe a la atención prestada al fenómeno por investigadores de los propios países, así como a que ambos casos son objeto de estudio de investigadores internacionales debido al establecimiento de relaciones de colaboración.

- La ciencia sobre desertificación a nivel internacional y también en el caso español, se estructura en *clusters* en torno a algunos autores clave que lideran grupos de investigación y son capaces de establecer conexiones con otros grupos de investigación.

- La ciencia generada sobre la desertificación se puede clasificar en dos corrientes: *land y soil approach*. El *land approach* (paisaje-territorio) interrelaciona la desertificación con cuestiones sociológicas, antropológicas, económicas y políticas, es decir con ámbitos de las ciencias sociales. Por su parte el *soil approach* (suelo) se vincula exclusivamente con ciencia aplicada en distintos campos, es una aproximación a la desertificación más reduccionista y vinculada a las ciencias naturales.

- La priorización del enfoque *soil approach* (suelo) frente al *land approach* (paisaje-territorio), da lugar al sesgo de las medidas anti-desertificación promovidas hacia visiones tecnocráticas, no necesariamente adaptadas a los contextos locales.

- La implementación de los resultados científicos en materia de desertificación es aún una asignatura pendiente. El uso del número de referencias publicadas en revistas indexadas en el *Journal Citation Report*, como indicador de la valía profesional de los investigadores, induce a que se priorice la publicación de resultados frente a la implementación de los mismos.

- La literatura científica recogida en la base bibliográfica *Web of Science*, la de mayor repercusión internacional, preferentemente compila referencias procedentes de revistas de impacto publicadas en inglés. Se ignora así la mayor parte del conocimiento científico generado en francés o español, con origen en África, Latinoamérica y España. Además, la publicación en inglés restringe el acceso a esta información por parte de muchos de los tomadores de decisiones y usuarios de la tierra en regiones afectadas, donde este idioma no es el predominante.

- Como ilustran el caso español y argentino la mayor parte de la literatura científica de impacto internacional se genera en universidades y centros de investigación. Son escasas las colaboraciones con otro tipo de instituciones como empresas, organizaciones sociales o centros de transferencia y extensión agraria. La endogamia colaborativa entre los centros de investigación y universidades, así como algunas ideas preconcebidas sobre qué es ciencia publicable, dificultan la difusión de conocimiento tradicional sostenible, que si bien no siempre está metodológicamente testado y sistematizado, forma igualmente parte legítima del conocimiento relativo a la gestión sostenible de la tierra.

- La labor de difusión de resultados aplicados, así como el análisis específico de las necesidades, prioridades, capacidades y medidas prácticas implementadas por los usuarios, actualmente se limita a informes técnicos y otros tipos de literatura gris. Este tipo de documentos es totalmente invisible para las bases de datos científicas y por ello difícilmente se integran en lo que se considera literatura científica de impacto.

- La llamada de atención de la Convención de Lucha Contra la Desertificación acerca del valor del conocimiento tradicional y la aparición de corrientes científicas innovadoras como la Etnopedología son señales alentadoras para que los gestores e investigadores vuelvan la vista hacia la sabiduría, los intereses y las necesidades de los usuarios de la tierra.

12.1.3. El conocimiento tradicional y los usuarios de la tierra, agentes clave en la implementación del manejo sostenible del suelo

- La agricultura en la comarca de Las Vegas en palabras de los propios agricultores “es una actividad de supervivientes”. La cercanía a Madrid podría suponer una ventaja, al ser este uno de los núcleos de consumo más importantes del país. En cambio, el bajo precio de los productos agrarios, la falta de relevo generacional y el recuerdo de la ferviente dinámica *push-pull* activa en la zona hasta el inicio de la crisis, hacen que muchos agricultores expresen que su actividad es marginal y que no da para vivir dignamente si no se complementa con otras rentas.

- Los agricultores de Las Vegas generalmente perpetúan la tradición familiar vinculada al campo. La base de su conocimiento en torno al manejo del suelo y otras prácticas agrarias se ha consolidado generación tras generación y a través de las redes comunitarias informales.

- El conocimiento local compartido es coherente en gran medida con el conocimiento científico del suelo generado en la zona. Los agricultores identifican factores físicos visibles, algunos factores químicos que afectan a la productividad (ej. materia orgánica) y tienen más dificultades para identificar factores para los que se requieren análisis químicos, como es el caso del pH o la salinidad.

- A pesar del nivel medio-alto de conocimiento de los agricultores respecto al suelo, se detecta una profunda brecha entre la importancia que los usuarios de la tierra y los investigadores otorgan a la identificación y control de la erosión.

- La erosión es uno de los agentes biofísicos más activos de la desertificación. No obstante, la pérdida de suelo no está arraigada en el imaginario de los agricultores como un problema grave. La erosión les preocupa en la medida que afecta a la pérdida de fertilidad del suelo y a la productividad de sus cosechas, pero no por su impacto ambiental.

- En el caso de los viticultores entrevistados, frenar la erosión no es una de sus prioridades porque entienden que puede ser un problema a largo plazo pero que hay cuestiones más inmediatas y fácilmente gestionables (ej. disponibilidad de agua y nutrientes o pérdida de cosechas por la caza), que afectan igualmente a su productividad. Esta es una señal del papel diferenciado que las variables lentas (ej. pérdida de suelo) y rápidas (ej. pérdida de fertilidad) de degradación del suelo, juegan en la función de producción de los agricultores.

- Cuando se pregunta a los usuarios por el tipo de medidas de mejora que podrían implementar, proponen de manera espontánea acciones como la incorporación de materia orgánica, la mejora del laboreo, el uso de fertilizantes, la modificación de la pendiente o la mejora del uso de pesticidas. En general, medidas que afectan a la productividad, más que a la pérdida de suelo (excepto en el caso de la pendiente o el laboreo, aunque respecto al laboreo es necesario profundizar en el tipo de propuestas planteadas).

- A pesar de las dificultades para identificar la erosión, la receptividad de los agricultores hacia técnicas de manejo sostenible no es desdeñable, siempre y cuando el coste económico no les sea perjudicial, reciban algún retorno de esta inversión (ej. calidad o precio del producto) y se sientan técnicamente respaldados.

- En cuanto a los costes de las técnicas de manejo sostenible, como el uso de cubiertas vegetales en viñedo y olivar, a los agricultores les condiciona el coste directo de implantación y mantenimiento (semillas, herbicidas o laboreo) y les preocupa su efecto sobre la calidad y cantidad de cosecha, por la aparición de especies no deseadas o la competencia por el agua y los nutrientes.

- En los pocos casos en los que los agricultores se han animado a experimentar con cubiertas vegetales, su uso no se adopta por la capacidad de protección del suelo, sino como estrategia para reducir costes ahorrando en laboreo y combustible. Además, los agricultores frecuentemente expresan que el mantenimiento de cubiertas vegetales es una técnica socialmente rechazada, ya que para la cultura tradicional, dejar que prolifere la vegetación espontánea es señal de “ser vago” o de “no saber trabajar la tierra”.

- Debido a los costes y a la incertidumbre sobre la eficacia de algunas técnicas de manejo sostenible, antes de lanzarse a la innovación, los usuarios prefieren constatar con sus propios ojos cuales son los efectos de estas técnicas.

- Los usuarios reconocen la necesidad de mejorar su capacitación sobre técnicas de manejo sostenible y conservación del suelo.

12.1.4. Los servicios de extensión y transferencia agraria, bisagra entre ciencia e implementación

- Los servicios de transferencia y extensión agraria y otras instituciones públicas vinculadas al sector (ej. Consejería de Medio Ambiente, Confederaciones Hidrográficas, Oficinas Comarcales, etc.) son concebidas por los usuarios desde una perspectiva dual. Por una parte, los agricultores los ven como fiscalizadores de su actividad en cuanto al cumplimiento de normativas no siempre bien divulgadas. Por otra, son un referente en cuanto a la consulta de dudas concretas sobre el manejo de los cultivos y otras prácticas agrarias (entre ellas las relacionadas con el suelo) y valoran positivamente su importancia como canalizadores de recursos financieros.

- Frecuentemente, el lenguaje de las comunicaciones oficiales o de las sesiones de capacitación y transferencia resulta complicado, ambiguo, excesivamente técnico y alejado del léxico popular empleado respecto a los suelos o las prácticas agrarias. Esto se debe en parte al arraigo, entre los científicos y técnicos, de la idea de que para ser riguroso hay que emplear un lenguaje académico.

12.2. RECOMENDACIONES

1. Es necesario hacer una profunda revisión del Programa de Acción Nacional Contra la Desertificación, dotándolo de un presupuesto específico y fortaleciendo la atención prestada a los impactos de la urbanización como agente degradador del suelo. Así mismo en el marco del PAND debe reflexionarse sobre las políticas, planes y programas que fomentaron el boom inmobiliario y su potencial resurgimiento a medio y largo plazo.

2. Es importante identificar las variables lentas (ej. pérdida de suelo en el contexto de Las Vegas) y rápidas (ej. sobreexplotación del suelo) que influyen en los procesos de desertificación y diseñar estrategias de acción específicas respecto a ellas, considerando el peso diferenciado que este tipo de variables desempeñan en la función de producción de los usuarios de la tierra.

3. Es necesario el desarrollo de modelos que permitan prever los escenarios futuros de los sistemas agrarios sometidos tanto a dinámicas de intensificación, como de abandono, así como de aquellos que han sido transformados a uso urbano. Y atendiendo a los resultados de estos modelos implementar estrategias de planificación del territorio y políticas coherentes con las necesidades de las generaciones presentes y futuras, y sobre todo con los límites de los ecosistemas.

4. Debe invertirse en el desarrollo de la ciencia del suelo y en la generación de relaciones de cooperación entre investigadores y usuarios, de forma que el conocimiento generado sea útil no sólo en el ámbito teórico sino también en el práctico. La formulación e implementación de políticas anti-desertificación eficaces, así como el desarrollo de técnicas de mejora de gestión del suelo depende estrechamente del avance científico y de su combinación con el saber-hacer tradicional de los usuarios de la tierra.

5. Las corrientes científicas *soil approach* (suelo) y *land approach* (paisaje-territorio) desempeñan una labor importante en la generación de conocimiento formal y deben ser equitativamente desarrolladas por los expertos y consideradas por los tomadores de decisiones.

6. La implementación del conocimiento científico debe convertirse en una prioridad para los investigadores y las instituciones relacionadas con la ciencia del suelo. En casos como el de España, en el que la ciencia se financia básicamente de recursos públicos extremadamente escasos, no invertir en desarrollo supone una pérdida de oportunidades. Si no se avanza en la implementación de resultados, se pierde una ocasión única para visibilizar por qué es preciso apostar por la ciencia, ya que esta es una herramienta útil para la conservación del suelo.

7. Es indispensbale fomentar las colaboraciones entre centros de investigación y universidades, con otro tipo de instituciones como empresas, organizaciones sociales o centros de transferencia y extensión agraria. Este tipo de colaboraciones son esenciales a la hora de facilitar la difusión de los resultados obtenidos, así como para identificar y analizar técnicamente las necesidades y prioridades de los usuarios de la tierra en materia de lucha contra la desertificación.

8. Las líneas de investigación promovidas desde los centros agrarios públicos deben nutrirse de la experiencia y prioridades expresadas por los usuarios y no fundamentarse en los

intereses de las instituciones, de los propios investigadores o en la perpetuación de líneas de trabajo antiguamente consolidadas. La organización de talleres participativos para la identificación de las líneas de trabajo de los proyectos de investigación, es una buena estrategia para estrechar las relaciones entre usuarios y científicos.

9. El arraigo de la visión productivista entre los usuarios de la tierra y su entorno hace evidente la necesidad de apostar por estrategias de sensibilización y capacitación. A través de la combinación de acciones políticas, formación e incentivos se puede fidelizar a los usuarios de la tierra como agentes activos para frenar la degradación del suelo. Este tipo de estrategias deben ser una prioridad para los responsables de la implementación de las medidas agroambientales dictadas por la Política Agraria Común (PAC).

10. Los servicios de transferencia y extensión agraria deben desempeñar un papel clave en el acompañamiento de los usuarios de la tierra y en la sensibilización y concienciación sobre la erosión y otros agentes de la desertificación, así como en el desarrollo de investigación aplicada y en la difusión de los resultados de la misma.

11. Los estudios sobre la efectividad de prácticas de manejo sostenible como las cubiertas vegetales deben complementarse con estudios comparativos acerca de la competencia por agua y nutrientes entre el olivar/viñedo y la cubierta, así como sobre las propiedades organolépticas del producto final (aceite de oliva/vino), cuestiones que resultan claves para que los usuarios decidan poner en práctica este tipo de técnicas.

12. Las experiencias demostrativas de buenas prácticas de manejo, adaptadas a los contextos locales, o los foros de intercambio de experiencias entre agricultores innovadores, son iniciativas motivadoras para otros usuarios, que deben ser fomentadas desde los centros de transferencia y extensión agraria, y apoyadas a nivel técnico y económico.

13. Respecto a la divulgación de las normativas de obligado cumplimiento y a la transferencia de información técnica y política de utilidad para los usuarios (ej. nueva estructura de la PAC), los servicios de transferencia y demás instituciones competentes, deben hacer un esfuerzo por elaborar mensajes sencillos, precisos e inteligibles. Adaptar el lenguaje científico y técnico no significa perder veracidad o ser impreciso, sino facilitar la compresión a través de ejemplos cercanos y cuestiones prácticas que atraigan a los usuarios.

14. La responsabilidad de liderar la confluencia entre el saber-hacer tradicional y la ciencia, a nivel institucional, recae en los centros de transferencia y extensión, y para ello necesitan fortalecerse tanto económica como socialmente. Sin embargo en las últimas décadas han tendido a desaparecer. Esta es otra de las cuestiones en las que tanto el PAND, como las administraciones autonómicas deben hacer hincapié si existe realmente la voluntad política de frenar la desertificación.

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ANEXOS

01

Supporting Information How desertification research is addressed in Spain? Land versus Soil approaches. *Land Degradation & Development:* doi:10.1002/ldr.2344

S1. List of 1166 author's keywords grouped in 13 categories

(Some keywords are grouped when their differences are based on gender, plurals, suffixes or prefixes. The number of keywords grouped are in brackets)

CLIMATE ('climate')-29

1. climate
2. climate belts
3. climate change
4. climate gradient
5. climatic change
6. extreme events
7. glaciation
8. Heinrich events
9. Holocene
10. Mediterranean climate
11. meteorology and atmospheric dynamics climatology, turbulence, instruments and techniques
12. meterology and atmospheric dynamics (general)
13. microclimate
14. northern-hemisphere glaciation
15. palaeoclimatic evidence
16. palaeoclimatology
17. palaeoecology
18. palaeoenvironment
19. palaeogene
20. paleoclimate
21. Quaternary
22. Roman warm period
23. semiarid climate
24. semi-arid climate
25. semiarid condition
26. spell
27. Tertiary
28. weathering
29. weathering processes

PROJECT-3*

1. EU programs
2. EU project RECONDES
3. SOCRATES

DESERTIFICATION-DRYLANDS ('des-dryl')-31

1. arid environment* (2)
2. arid land*(2)
3. desert dust
4. desertification
5. desertification processes
6. desertification risk
7. desert-like surface features
8. dry environments
9. dryland*(2)
10. evaluation of desertification
11. hydrology (desertification)
12. land desertification
13. overgrazing desertification
14. semi*arid (2)
15. semi*arid area* (4)
16. semiarid ecosystems
17. semi*arid environment*(4)
18. semi*arid region*(3)
19. semiarid zones

POLICY-SOCIOECONOMIC ('poli-soc')-18

1. contingent valuation
2. decision making
3. developmental stage
4. drought-insurance
5. economic valuation
6. ecosystem services
7. land reclamation
8. monitor environmental policies
9. participative management
10. policy impacts
11. public works
12. socioeconomic drivers
13. socio-economic impact
14. soil conservation policy
15. stakeholders
16. sustainability
17. sustainable development
18. sustainable planning

N.D.-17*

1. air quality
2. beta-glucosidase
3. carbohydrates
4. contributing area*(2)
5. european rabbit
6. global events
7. intensity
8. linear unmixing
9. motorway slopes
10. oryctolagus cuniculus
11. provenance
12. roadfill
13. roadside
14. roadside slopes
15. security
16. temporal fragmentation

GEOLOGY-GEOMORPHOLOGY ('geol-geom')-69

1. alluvial fans
2. aspect
3. badlands
4. coast creative action
5. continental carbonates
6. cycles
7. doline
8. dune field expansion
9. early Cretaceous
10. eco-geomorphology
11. Eocene
12. evaporites
13. fan surface dynamics
14. fault-bounded aeolian dune field
15. geochronological evolution
16. geomorphic process
17. geomorphodynamics
18. hillslope*(2)
19. hillslope scale
20. Jurassic
21. karst
22. kite and blimp platforms
23. late Pleistocene
24. local topography
25. marine-erg margin
26. micro relief
27. microtopography
28. Mounds
29. Oligocene
30. pedogenic carbonates
31. Permian-Triassic
32. playa*(2)
33. Pliocene climate
34. quaternary morphogenesis
35. rambla systems
36. rangelands
37. rocky sea area
38. sand composition
39. sand sheets
40. sandstones
41. sea*level (2)
42. sea-level fluctuations
43. semi-arid hillslopes
44. semiarid landscape
45. slope
46. slope angle
47. slope aspect
48. slope orientation
49. soil geomorphology
50. steep hillslopes
51. steep slopes
52. subtidal
53. talus flatirons
54. tectonic disturbances
55. tectonism
56. Teruel graben
57. topographic indices
58. topographic positions
59. topographical thresholds
60. topography
61. tufa
62. ultrapotassic basalt
63. WADI
64. wetland morphology
65. yardang
66. Younger Tryas

EROSION-SOIL DEGRADATION ('EROS-SDG')-153

1. aeolian
2. aeolian deposits
3. aeolian erosion
4. aeolian sand
5. aerosol
6. animal tracks
7. animal trampling
8. anthropogenic disturbance
9. anthropogenic pollution
10. ash
11. bank gully
12. bed scouring-sedimentation balance
13. blowouts
14. channel changes
15. channel management
16. channel morphology
17. channel roughness
18. channel stabilisation
19. chemical degradation
20. chemical erosion
21. coeval grains
22. concentrated flow erosion
23. connectivity
24. costs of erosion
25. degradation
26. degraded mediterranean ecosystems
27. degraded soil
28. detachment dynamics
29. dissection
30. environmental impact
31. ephemeral channels
32. ephemeral dryland river channels
33. ephemeral flow
34. ephemeral gullies
35. ephemeral streams
36. erg-margin
37. erodibility
38. erosion
39. erosion and sediment transport
40. erosion control
41. erosion control measures
42. erosion map
43. erosion mechanisms
44. erosion mitigation
45. erosion pins
46. erosion plots
47. erosion probability
48. erosion processes
49. erosion rated
50. erosion rates
51. erosion rates and patterns
52. erosion thresholds
53. fire
54. fire severity
55. fluting
56. fluvial erosion
57. fluvial sands
58. forest fires
59. fractional cover
60. general transitory scouring
61. gold mining
62. gullies
63. gully
64. gully development
65. gully erosion
66. gully erosion monitoring
67. gully head erosion
68. gully head morphology
69. gully heads
70. gully-head retreat
71. gullying
72. heavy metals
73. hortonian flow
74. human impact
75. hydrological connectivity
76. hydrosedimentological response
77. interrill erosion
78. land degradation
79. land degradation and desertification

continue

80. land degradation monitoring
81. local disturbances
82. long-term effect
83. metal pollution
84. methods of erosion evaluation
85. migration of elements
86. mine pollution
87. mine tailings
88. mining
89. mining soils
90. morphological runoff zone
91. off site impacts
92. off-site effects
93. overgrazing
94. piping
95. raindrop size
96. rainfall erosivity
97. rainfall*runoff (2)
98. rapid erosion detection
99. repeated fire
100. resistance
101. rill network
102. risks of erosion
103. run*off (2)
104. runoff and erosion control
105. runoff generation
106. runoff modelling
107. runoff redistribution
108. runoff water quality
109. runon
110. saltation
111. sand
112. sandblasting
113. scour and fill
114. sediment
115. sediment dynamics
116. sediment redistribution
117. sediment response
118. sediment size distribution
119. sediment transport
120. sediment yield
121. sedimentation
122. sheep trails
123. slope stability
124. soil contaminants
125. soil crust*(2)
126. soil degradation
127. soil erodibility
128. soil erodibility by wind
129. soil erosion
130. soil loss*(2)
131. soil water erosion
132. soil-erosion rates
133. specific sediment yield
134. splash erosion
135. stream bank erosion
136. surface runoff generation
137. suspension
138. tailings erosion
139. terrace failure
140. teruel coalfield
141. tillage erosion
142. vegetation-erosion relationships
143. ventifacts
144. vertical dust flux
145. water erosion
146. water soil erosion
147. wind erosion
148. wind-erodible fraction
149. wind-water interaction

LAND MANAGEMENT-LAND USE (‘land-use’)-143

1. abandoned fields
2. abandoned land
3. abandonment
4. abiotic amelioration
5. adaptive management
6. agricultural land
7. agricultural soil
8. agricultural soil conservation
9. agricultural terrace
10. agriculture
11. agriculture management
12. agri-environmental measures
13. almond monocultures
14. almond orchards
15. alperujo
16. animal production systems
17. barley
18. barley residues
19. beet vinasse
20. bench terrace fields
21. buffer zones
22. burnt stubble
23. by-product obtained after the two-step olive oil extraction process
24. cereal-fallow rotation
25. chipped pruned branches
26. chisel ploughing
27. citrus orchards
28. conservation
29. conservation tillage
30. cotton gin crushed compost
31. cover crop management
32. cover crops
33. crop residues
34. crop rotation
35. crop stubble
36. crop suitability
37. crushed cotton gin compost
38. desertification remediation
39. dryland cereal farming
40. dryland cropping
41. dryland farming
42. dry-land farming
43. ecological restoration
44. embankment
45. extensification
46. fallowing
47. farmland abandonment
48. farmland set-aside
49. fertilization
50. floodwater farming
51. fodder crops
52. fruit-tree orchards
53. grapevine growing
54. grasslands
55. grasslands restoration
56. ground cover changes
57. herbicide
58. hydroseeding
59. intercropping
60. irrigation
61. land abandonment
62. land cover
63. land evaluation
64. land management
65. land rehabilitation
66. land use
67. land use change* (2)
68. land use*cover change (2)
69. landscape conservation
70. landuse
71. land-use abandonment
72. land-use change*(2)
73. land-use planning
74. management
75. mouldboard plough
76. mouldboard ploughing
77. mulching

continue

78. municipal solid by-product
79. municipal solid waste
80. municipal solid waste compost
81. NATURA 2000 areas
82. natural area
83. no till
84. no*tillage (2)
85. oil mill waste
86. olive oil mill waste
87. olive orchard
88. olive orchards
89. organic amendment*(2)
90. parallel contour seeding
91. pest control
92. phytostabilization
93. pig slurry
94. plough
95. poultry manure
96. prunus dulcis *(2)
97. quarry restoration
98. rain fed cereals
99. rainfed tree crops
100. range management
101. reduced tillage
102. regeneration strategy
103. residue cover
104. restoration
105. restoration ecology
106. revegetation
107. revegetation strategies
108. scraping
109. set-aside land
110. sewage sludge
111. soil amendment
112. soil and water conservation
113. soil conservation
114. soil conservation practices
115. soil management
116. soil organic amendment
117. soil restoration
118. soil surface cover
119. soil tillage
120. standing residues
121. step terraces
122. straw mulch
123. support irrigation
124. sustainable agriculture
125. terraced soils
126. terraces
127. terracing
128. tillage
129. tillage intensity
130. tillage system
131. tillage translocation
132. uncultivated soils
133. vegetal mulch
134. vineyard*(2)
135. Vitis vinifera
136. yield

LOCATION -63*

1. arid lands (central Ebro valley, NE-Spain)
2. Arid Mediterranean region
3. Bardenas Reales
4. Betic cordillera
5. Cabo de Gata
6. Cabo de Gata-Nijar natural Park
7. Canary Islands
8. Central and Northeastern Spain
9. Central Ebro valley
10. Central Spain
11. Central Spanish Pyrenees
12. Central system
13. Duero depression
14. eastern Spain
15. Ebro basin
16. Ebro depression
17. Ebro valley
18. Europe
19. Guadalentin
20. Guadiana basin
21. Iberian península(2)*
22. Iberian range
23. Lanjaron
24. marl lake
25. Mediterranean
26. Mediterranean area* (2)
27. Mediterranean basin
28. Mediterranean catchment
29. Mediterranean Islands
30. Mediterranean region
31. Mediterranean slopes
32. Mediterranean soils
33. Mediterranean Spain
34. Middle Ebro valley
35. Murcia
36. Murcia region
37. Niger
38. Nijar natural park
39. North-East Spain
40. Pulpi Basin
41. Pyrenees
42. rift basins
43. Rodalquilar
44. SE Spain
45. Semi-Arid Mediterranean
46. Semiarid South-East Spain
47. Semi*arid Spain (2)
48. Sierra de Gata
49. South*East * Spain (7)
50. Spain
51. Tabernas
52. Tierra de pinares
53. Yeste
54. Zaragoza

SOIL ANALYSIS ('soil-analysis')-195

1. absorption features
2. acid phosphatase
3. active carbon
4. aggregate stability
5. alkalinisation
6. antecedent moisture
7. antecedent soil moisture
8. arid and semiarid soils
9. arid ecosystems
10. arid soils
11. bacillus cereus
12. bare soil
13. binding energies
14. biological soil crust
15. biophysical determinants
16. bioturbation
17. bulk density
18. calcareous and gypsiferous soils
19. calcareous soil*(2)
20. calcretes
21. carbon sequestration
22. carbonate grains
23. carbonate nodules
24. chemical properties
25. clay minerals
26. CO(2)
27. composts
28. contamination risks
29. copper
30. crusting
31. cyanobacteria
32. dispersive soils
33. dry aggregate size distribution
34. elemental and functional group composition
35. enzymatic activities
36. enzyme activities
37. eroded organic carbon
38. exhaustion of material
39. facilitation
40. fertility loss

continue

41. forest soil*(2)
42. geochemical composition
43. geochemistry
44. gypsic horizon
45. gypsiferous soils
46. gypsu* (2)
47. gypsum hills
48. hazard
49. humic acids
50. humic substances
51. humidity
52. inceptisols
53. iron bearing minerals
54. labile c fractions
55. leaching
56. leptosols
57. lithology
58. litter
59. litter cover
60. luvisol
61. metal availability
62. microbial biomass* (2)
63. microbial respiration
64. microcrust
65. micromorphology
66. mobility
67. mollisols
68. nematode
69. net ecosystem carbon balance
70. nickel
71. nitrates
72. nitrogen
73. nutrient availability
74. nutrients
75. organic and inorganic soil carbon
76. organic carbon
77. organic matter
78. organic wastes
79. palaeosols
80. paleosols
81. particulate organic carbon
82. phaeozems
83. phosphatase
84. phosphorus
85. physical and chemical properties
86. physical crust
87. physical properties
88. physical soil crust*(2)
89. porosity
90. regosols
91. remediation
92. Rendzines
93. rock fragment cover
94. rock fragment properties
95. rock fragments
96. rock outcrop
97. roughness
98. roughness length
99. salinisation
100. salinity
101. salinization
102. semiarid soils
103. slaking
104. smectite-rich clays
105. soc
106. soil
107. soil aggregation
108. soil carbon evaluation
109. soil carbon sequestration
110. soil carbon stabilization
111. soil carbon storage
112. soil chemistry
113. soil chronosequence
114. soil classification
115. soil CO(2) efflux
116. soil compaction
117. soil composition
118. soil depth
119. soil detachment
120. soil enzymatic activities
121. soil fertility
122. soil functioning
123. soil microbial biomass*(2)
124. soil micromorphology
125. soil moisture
126. soil moisture patterns
127. soil moisture variability
128. soil organic carbon
129. soil phases
130. soil physical properties
131. soil properties
132. soil protection
133. soil quality
134. soil redistribution
135. soil respiration
136. soil salinity
137. soil salinization
138. soil sodicity
139. soil strength
140. soil structure
141. soil surface components
142. soil surface condition
143. soil surface properties
144. soil surface roughness
145. soil temperature
146. soil texture
147. soil thickness
148. soil transport
149. soil variability
150. soil water availability
151. soil water content
152. soil water potential
153. soil water retention
154. soil-surface conditions
155. soilsurvey
156. solute release
157. source-sink areas
158. spatial variation in soil properties
159. stabilisation
160. stable isotopes
161. stand structure
162. stoniness
163. stony substrates
164. structural stability
165. successive rotational slides
166. surface conditions
167. surface energy balance
168. surface fluxes
169. surface properties
170. surface roughness
171. surface soil properties
172. surface storage
173. tension cracks
174. terrain attributes
175. thin sections
176. topsoil
177. tracers
178. trampling
179. trap efficiency
180. travertines
181. urease
182. vermicomposts
183. volcanic soils
184. water-soluble c
185. water-soluble carbohydrates
186. wetness threshold
187. xeric soils
188. Zinc
189. Zn

STATISTICS- MODELLING-INDICATORS ('stat-mod')-184

1. aerial photograph
2. alternative long-term states
3. ATP content
4. browsing
5. caesium-134
6. caesium-137
7. calibration
8. carbon isotopes
9. cesium-137
10. chronosequences
11. close range aerial photogrammetry
12. coherence
13. collector device* (2)
14. conditional simulation
15. controlling factors
16. correlation analysis
17. cover factor
18. cramer-von mises test
19. crum
20. curve number
21. decomposition models
22. DELTA C-13
23. DELTA N-15
24. DELTA O-18
25. DEM (digital elevation model)
26. diffuse reflectance spectroscopy
27. distributed modeling
28. disturbance
29. dry sieving
30. eddy covariance
31. electromagnetic induction
32. EM38
33. end members
34. environmental quality
35. ESR and NMR spectroscopies
36. experimental field
37. experimental fire
38. experimental methods
39. experimental plots
40. factors
41. fallout Cs-137
42. field methods
43. field spectra
44. flat sieve
45. fluorescence spectroscopy
46. fractals
47. frequency-magnitude relationships
48. ftir spectroscopy
49. future trajectories
50. gamma distribution
51. geographic information systems (GIS)
52. geo-indicators
53. geostatistics
54. GEOWEPP
55. GIS
56. high resolution images
57. hyperspectral
58. hyperspectral remote sensing
59. IDRISI GIS
60. image analysis
61. indicator*(2)
62. INSAR
63. INSAR coherence
64. integrated assessment (IA)
65. interaction models
66. isotopic geochemistry
67. laboratory
68. lacunarity
69. land cover classification
70. land degradation indicators
71. landsat tm time series analysis
72. laser scanner
73. mapping
74. measurement variability
75. MICROLEIS
76. microplot scale
77. MIR
78. model validation
79. modelling
80. modelling framework
81. moderate resolution imaging spectroradiometer
82. modified fourier index
83. monitoring
84. monte carlo
85. multifractal analysis
86. multi-proxy
87. multispectral
88. multi-temporal assessment
89. multivariable analysis
90. multivariant analysis
91. NDVI
92. NIR
93. normalized difference vegetation index (NDVI)
94. openlisem
95. orthophotographs
96. palaeoenvironmental reconstruction
97. parameterization
98. pattern analysis
99. PCA
100. photogrammetry
101. photography
102. pin meter
103. planning scenarios
104. plot
105. policy support system (PSS)
106. pollen analysis
107. pollen diagrams
108. power law
109. precipitation concentration index
110. principal component analysis
111. process-based models
112. profilometer techniques
113. quickbird
114. radar
115. radiocarbon dating
116. rainfall simulation*(3)
117. rainfall simulator
118. randomization test
119. ratio coherence
120. regional land classification
121. remote sensing
122. response units
123. rotary sieve
124. roughness indexes
125. RUSLE
126. SADIE
127. saline lake models
128. sar interferometry
129. scale
130. scale dependency
131. scale issues
132. scale relationship
133. scale-dependence
134. scarp retreat rates
135. scenarios
136. sedd
137. sensitivity analysis
138. shadow analysis
139. simulated rainfall
140. simulation
141. simulation model* (2)
142. small-format aerial photography
143. soil degradation evaluation
144. soil degradation index
145. soil erodibility factor (K)
146. soil erosion mapping
147. soil erosion modelling
148. soil erosion risk assessment
149. soil indicators
150. soil quality indices
151. spatial analysis
152. spatial association
153. spatial decision support system (SDSS)
154. spatial metrics
155. spatial pattern*(2)
156. spatial resolution
157. spatial transformation
158. spatially distributed model
159. Spearman test
160. spectral angle mapper
161. spectral unmixing

continue

162. speros model
163. state-and-transition models
164. stratification ratio
165. structural equation modelling
166. system dynamic model
167. tillage simulation
168. time scale
169. time series
170. TLS
171. validation
172. vegetation index
173. volumetric variation curves
174. wind tunnel
175. winxspro

WATER ('water')-81

1. application of wfd
2. aquifer recharge
3. catchment*(2)
4. catchment management
5. catchment scale
6. cation exchange capacity
7. check*dam*(2)
8. check dam sedimentation
9. drought
10. dry periods
11. ecohydrological interrelationships
12. ecohydrology
13. ecological filters
14. flood*(2)
15. fluvial
16. fluvial basin
17. fluvial deposits
18. freshwater carbonate tufa
19. hill*slope hydrology(2)
20. hortonian infiltration
21. hydraulic adjustments
22. hydrogeology
23. hydrolase activities
24. hydrological and territorial planning
25. hydrological response
26. hydrologically similar surfaces
27. hydrology
28. hydromorphology
29. hyperconcentrated flows
30. infiltration
31. infiltration rate
32. macro-pore flow
33. meromixis
34. microcatchment
35. overland flow
36. palustrine
37. peak discharge
38. pluviometric gradient
39. precipitation trends
40. precipitation use efficiency
41. rainfall
42. rainfall dynamics
43. rainfall events
44. rainfall intensity
45. rainfall trends
46. rainfall variability
47. reservoir sedimentation
48. river capture
49. saturation excess overland flow
50. semiarid hydrology
51. stem-root flow
52. storms
53. stream
54. subsidence
55. surface land hydrology
56. surface water redistribution
57. water aggregate stability
58. water availability
59. water balance
60. water content
61. water dispersible clay
62. water harvesting
63. water holding capacity
64. water infiltration
65. water management
66. water pollution
67. water potential
68. water redistribution
69. water repellency
70. water storage
71. water stress
72. water use
73. water-use efficiency
74. wetting-dry cycle
75. WFD implementation

ECOLOGY-VEGETATION-BIODIVERSITY ('eco-veg-bd')-180

1. afforestation
2. animal nutrition
3. arbuscular mycorrhiza*(3)
4. arid areas
5. autochthonous
6. basin dynamics
7. biodiversity
8. boundary effect
9. Brachypodium retusum
10. cactus*(2)
11. classification tree analysis
12. colonisation
13. diatoms
14. Diploschistes diacapsis
15. dispersal
16. dispersion
17. diversity
18. dominant species
19. drainage basin
20. drought stress
21. dry vegetation
22. dynamics
23. ecological strategies
24. ecology
25. ecophysiology
26. ecosystem
27. ecosystem functioning
28. ecotone
29. environmental limitations
30. essential oils
31. evapotranspiration
32. fast-growing species
33. fine roots
34. floristic composition
35. forest types
36. functional traits
37. functioning
38. Glomus claroideum
39. gradient
40. gypsiferous steppe
41. historical biogeography

continue

42. hot-spots
43. indigenous species
44. individual shrubs
45. inhibition
46. Juniperus thurifera
47. landscape
48. landscape evolution
49. landscape fragmentation
50. landscape function analysis
51. landscape response
52. Lavandula spp.
53. leafless shrubs
54. legumes
55. lichen*(2)
56. local species
57. maquis
58. matorral
59. Medicago shrubs
60. Mediterranean agro-ecosystem
61. Mediterranean ecosystems
62. Mediterranean environment
63. Mediterranean forests
64. Mediterranean gorse shrubland
65. Mediterranean grasslands
66. Mediterranean shrubs
67. Mediterranean vegetation
68. Mediterranean-type shrublands
69. Messor bouvieri
70. metal tolerant plants
71. microenvironment
72. moss
73. neighboring vegetation
74. novel soil-plant systems
75. nurse effect
76. Olea
77. Olea europaea subsp sylvestris
78. Opuntia
79. Opuntia ficus-indica
80. palaeolimnology
81. patch size distribution
82. patched vegetation
83. patchy matorral
84. patchy vegetation
85. phenology
86. photosynthesis
87. Pinus halepensis
88. Pinus pinaster
89. Pistacia lentiscus
90. plant colonisation
91. plant community assembly
92. plant competition
93. plant composition
94. plant cover
95. plant diversity
96. plant functional diversity
97. plant growth form
98. plant morphology
99. plant mortality
100. plant repopulation
101. plant succession
102. plant traits
103. plant-cover strips
104. planting densities
105. plant-root activity
106. pollen
107. post-fire recovery
108. post-fire regeneration
109. relationship
110. respiration
111. resprouter*(2)
112. Retama sphaerocarpa
113. Rhamnus lycioides
114. riparian perennial vegetation
115. root
116. root area ratio
117. root cohesion
118. root strength
119. root-soil anchoring
120. sapling survival
121. secondary succession
122. seed bank
123. seed establishment
124. seed losses
125. seed mass
126. seed shape
127. seed size
128. self-organization
129. semiarid grasslands
130. semi-arid patchy
131. semiarid shrublands
132. semi-arid steppe
133. shear strength
134. shear stress
135. shrub encroachment
136. shrubs
137. spatial distribution
138. spatial heterogeneity
139. spatial isolation
140. species interactions
141. species richness
142. spontaneous grass cover
143. steppe*(2)
144. steppe wetlands
145. Stipa tenacissima
146. stomatal control
147. stress-resistant plants
148. system dynamics
149. thresholds
150. thuriferous juniper woodland
151. Ulex parviflorus
152. vegetation
153. vegetation architecture
154. vegetation cover
155. vegetation dynamics
156. vegetation history
157. vegetation influence
158. vegetation patch
159. vegetation pattern*(2)
160. vegetation recovery
161. vegetation regeneration
162. vegetation spatial patterns
163. vegetation/hydrologic spatial variability
164. vulnerable areas
165. weeds
166. wetland origin
167. wetlands
168. wild-aromatic plants
169. wildfire*(2)
170. xerophyte

Total Number of keywords 1166

S2. Basic concepts in social network

PARAMETER	LEVEL OF APPLICABILITY	DESCRIPTION	CALCULATION	UNITS
Density	*Network*	The proportion of ties in a network relative to the total number possible	$Density = \frac{2L}{g(g-1)}$	0-1
Centralization	*Network*	The difference between the number of links for each node divided by maximum possible sum of differences. A centralized network will have many of its links dispersed around one or a few nodes, while a decentralized network is one in which there is little variation between the number of links each node possesses.	$Centralization = \frac{\sum_{i=1}^{g}[C(n^*) - C(n_i)]}{max \sum_{i=1}^{g}[C(n^*) - C(n_i)]}$	0-1
Degree	*Node and network*	The count of the number of ties to other actors in the network.	$Node\ degree = C_D(n_i) = x_{i+} = \sum_j x_{ij} = \sum_j x_{ji}.$	absolute
			$Network\ degree = \frac{\sum_{i=1}^{g}[C_D(n^*) - C_D(n_i)]}{max \sum_{i=1}^{g}[C_D(n^*) - C_D(n_i)]} = \frac{\sum_{i=1}^{g}[C_D(n^*) - C_D(n_i)]}{[(g-1)(g-2)]}$	0-1
Closeness	*Node and network*	The degree an individual is near all other individuals in a network (directly or indirectly). It reflects the ability to access information through the "grapevine" of network members. Thus, closeness is the inverse of the sum of the shortest distances between each individual and every other person in the network.	$Node\ closeness = C_c(n_i) = [\sum_{j=1}^{g} d(n_i, n_j)]^{-1}$	absolute
			$Network\ closeness = \frac{\sum_{i=1}^{g}[C'_C(n^*) - C'_C(n_i)]}{[(g-2)(g-1)]/(2g-3)}$ $Where\ C'_C(n_i) = (g-1)C_c(n_i)\cdot$=standardized closeness	0-1
Betweenness	*Node and network*	The extent to which a node lies between other nodes in the network. This measure takes into account the connectivity of the node's neighbors, giving a higher value for nodes which bridge clusters. The measure reflects the number of people who a person is connecting indirectly through their direct links	$Node\ betweenness = C_B(n_i) = \sum_{j<k} g_{jk}(n_i)/g_{jk}$	absolute
			$Network\ betweenness = \frac{2\sum_{i=1}^{g}[C_B(n^*) - C_B(n_i)]}{[(g-1)^2(g-2)]}$	0-1
Clicke	*Network*	Groups are identified as 'cliques' if every individual is directly tied to every other individual, 'social circles' if there is less stringency of direct contact, which is imprecise, or as structurally cohesive blocks if precision is wanted.	-	-
Resources: Based on (Wasserman, 1994; Velázquez Álvarez, 2005)				

L=number of lines or relations present. g=total number of nodes $C_?(n_i)$ is an actor centrality index $C_?(n^*)$ is the largest value of a particular index that occurs across the g actors in the network= $max_i\ C_?(n_i)$

02

Cuestionario semiestructurado. Farmers's soil knowledge, perception and management in Las Vegas agricultural district, Madrid, Spain

STRUCTURED QUESTIONNAIRE ABOUT FARMER'S SOIL KNOWLEDGE, MANAGEMENT AND DEGRADATION PERCEPTION

Date:

Interview location: NºQ:

1. Age:
2. Gender: ☐ Male ☐ Female
3. Level of studies:
   - ☐ Primary School
   - ☐ Secondary School
   - ☐ Training college. Which specialization?
   - ☐ Bachelors degree. What degree?
4. Did you learn about soil notions along the Primary Education? ☐No ☐ Yes ☐ I do not remember.
5. Why are you involved in agriculture?
6. Do you hold a family relationship with agriculture? ☐No ☐ Yes. Through whom?
7. Would you like your children will involve on agriculture? ☐No ☐ Yes. Why?
8. Is the agriculture your main source of income? ☐No ☐ Yes. What other economic activities do you perform?
9. Would you change your main activity if you could? ☐No ☐ Yes. Why?
10. What crops do you grow?
    - ☐ Orchards
    - ☐ Cereals
    - ☐ Vineyards
    - ☐ Olive groves
    - ☐ Others?
11. Where do you hold agrarian plots?
12. How many hectares have your farm?
13. How long have you being farming these lands?
14. What management do you implement?

	Horticult.	Cereals	Vineyards	Olive groves	Others
a. No tillage					
b. Shallow tillage					
c. Deep tillage					
d. Cover crops					
e. Use of organic matters coming from crops					
f. Chemical fertilizers					
g. Manure and organic fertilizers					
h. Crop rotation					
i. Fallow					
j. Surface irrigation					
k. Sprinkle irrigation					
l. Drip irrigation					
m. Pesticides and herbicides					
n. Biological pest control					

15. Why do you use these practices and no others? They are…

a. the practices we have used all our life	
b. the most common practices in the area	
c. the most profitable practices	
d. the practices that receives more public financial aid	
e. the practices that I know	
f. the practices more environmental-friendly	
g. the practices that I must implement by law	
h. the practices recommended by the commercial brands	
i. the easiest practices	
j. the practices that provide the highest quality to the products	

16. What degradation problems affect your soils?

	Non-existing	Marginally relevant	Relevant	Very relevant	No answer
a. Erosion					
b. Compacting					
c. Pollution					
d. Acidity					
e. Alkalinity					
f. Salinization					
g. Low organic matter					
h. Low water retention					
i. Waterlogging					
j. Low fertility					
k. High slopes					

17. Do you think you can reduce or solve these problems? ☐No ☐ Yes How?

18. What kind of support would the farmers need to conserve or improve their soils?
☐Training
☐Financial support
☐Technology
☐Others (specify):

19. Woul you like to be trainned about any specific agrarian practice? ☐No ☐ Yes Which one?

20. When you need agrarian information where do you look for it?

☐ Agrarian Extension Services

☐Family

☐ Neighbors or familiar farmers

☐Agrarian associations

☐Commercial brands bulletins

☐Agrarian products centers

☐Radio

☐Press

☐Internet

☐Others (specify):